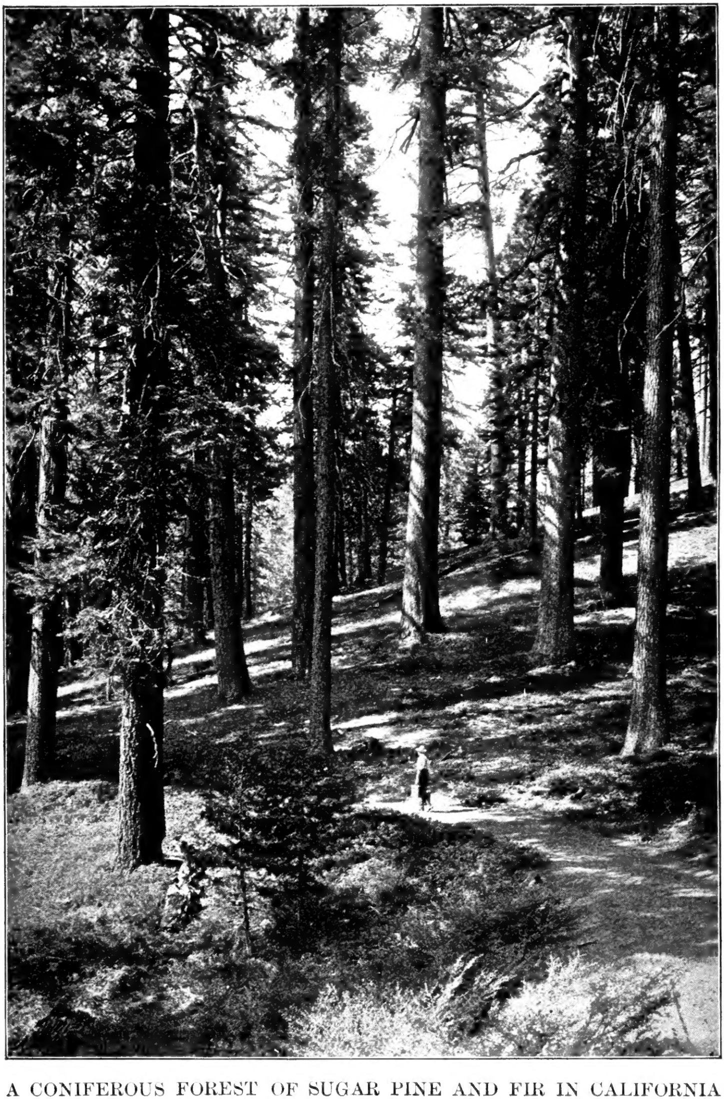
INTRODUCTION TO BOTANY

BERGEN AND CALDWELL



A CONIFEROUS FOREST OF SUGAR PINE AND FIR IN CALIFORNIA

INTRODUCTION TO BOTANY

BY

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PREFACE

This book treats the subject of botany from the same point of view that was adopted in the authors' "Practical Botany," but more briefly; that is, it endeavors to deal with the subject with constant reference to common educational, æsthetic, and practical interests in plant life. It also emphasizes the dynamic side of botany. The plant is not used primarily as a subject for dissection, nor for making a preserved specimen, but as an organism with a living to make — an organism that is forced to maintain its existence under conditions that are sometimes favorable and sometimes unfavorable to it. Constant effort has been made to render the style of the book simple and direct.

The object here sought is to present in a short course that kind of botanical knowledge which will especially interest the average secondary-school pupil, and which will be of most service to him as a means of education. Along with this training a good deal of other knowledge is presented, which should remain as a valued acquisition throughout the student's after life — knowledge of forest, field, wayside, farm, orchard, garden, and the industries. Since it has been shown that our disciplinary education may be useful in after life, mainly as the materials studied have elements in common with those later encountered, it becomes imperative that the elementary sciences should utilize in their content those things with which people are to come in contact. So much of the materials of botany is encountered by people in general throughout their lives that, according to recently accepted educational theories, this subject should have

peculiar educational significance. To this end those aspects of the plant world which touch human interests and activities ought to receive particular attention. It is essential, also, that the study be so shaped as to give the student a reasonable view of the phenomena of life as embodied in plants, for the average pupil (who does not go to college) will never again have so good an opportunity to learn about the simpler manifestations of life as is offered in his high-school course in botany. It is believed by the authors that every high-school pupil should be introduced to certain elementary and important facts regarding the life processes and problems of living things, and the first-hand study of plant life offers an especially favorable means of presenting these elementary biological truths.

The order of treatment here adopted is first to give a general notion of the world-wide distribution and importance of plants; then to enable the pupil to see the whole plant as a working machine; then to discuss more in detail the structure and work of the higher plants, each region of which performs a definite part of the work of the whole machine; then very briefly to present a general view of the great groups. Although throughout the book the plants used as the basis of study are usually those of common interest, a few of the most practical topics, such as timber and forestry, weeds, plant breeding, and the plant industries, are given separate treatment, with as much detail as is possible in a brief course. The structure, functions, and ecological relations of plants are presented throughout the book in a synthetic manner.

Questions pertaining to the interpretation and application of different features of plant life are introduced in the text and at the ends of chapters. Other similar questions raised by the teacher will be found helpful in presenting problems that the pupil should be able to solve in connection with his studies. Such problems help to develop the constant attitude of inquiry which science attempts to establish.

Valuable suggestions from many teachers and students of botany have been gladly received, and these will doubtless serve to render the book more helpful and usable than it otherwise would have been. Especial thanks are due to Dr. Norman MacLeod Harris of the Department of Bacteriology of The University of Chicago, who has read the chapter on bacteria; and to Mr. William L. Eikenberry of the University High School, Chicago, who by his frequent suggestions, based on extensive experience, has been constantly helpful in the preparation of this book.

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INTRODUCTION TO BOTANY

CHAPTER I

INTRODUCTORY

1. Interest in plants. All people are in some way interested in plants, although not every one recognizes that he has this interest. We all live largely on plants or plant products, and most of the world's workers earn their livelihood by some kind of industry which deals with plants or with their products. A glance at the food on any well-furnished table will suggest to what an extent our daily bill of fare consists of vegetable substances. Our animal foods — meat, milk, eggs, fish, and the rest — are only plant foods transformed more or less directly into animal tissues or animal secretions. Our spices and flavors and most of our medicines are plant substances or extracts. Part of our clothing is made from plant material. Our houses are often almost wholly constructed from timber, the furnishings are made from timber, and a home is scarcely complete without some growing plants, which assist in decorating the house and in giving pleasure to the occupants.

How raw materials derived from plants underlie most of the world's great industries cannot adequately be shown in a single paragraph. It is quite evident that the farmer, the gardener, the lumberman, the carpenter, the paper-maker, the cotton manufacturer, and the sail-maker are dealing with plants or with materials that are derived from them, but the multitudes of workers who make their living by sinking and operating oil wells, by refining petroleum, by mining and

marketing coal, or by any kind of manufacture in which the motive power is obtained by the aid of coal, oil, or gas used as fuel — all these people depend upon the products of the plant life that was abundant on the earth or in the seas during past ages. The air which we breathe is purified partly through processes by means of which green plants live. It is

FIG. 1. Sparse vegetation as seen upon the sand dunes along the shore of Lake Michigan

The wind-blown sand presents a poor living place for plants, although along the upper beach a fringe of trees and other plants has become established. In the view here shown the sand has been blown into definite ripples reaching down almost to the water of the lake

evident, then, that human life could not continue for a single week without the aid of substances produced by the life and growth of plants.

2. Plant production. The domesticated animals that are so extensively used to help man in his work, and those that he grows for food or for market, could not be cared for if it were not possible to have plants or plant products for their food.

If plant production were not so important to the world, there would be little need of having domesticated animals. Our

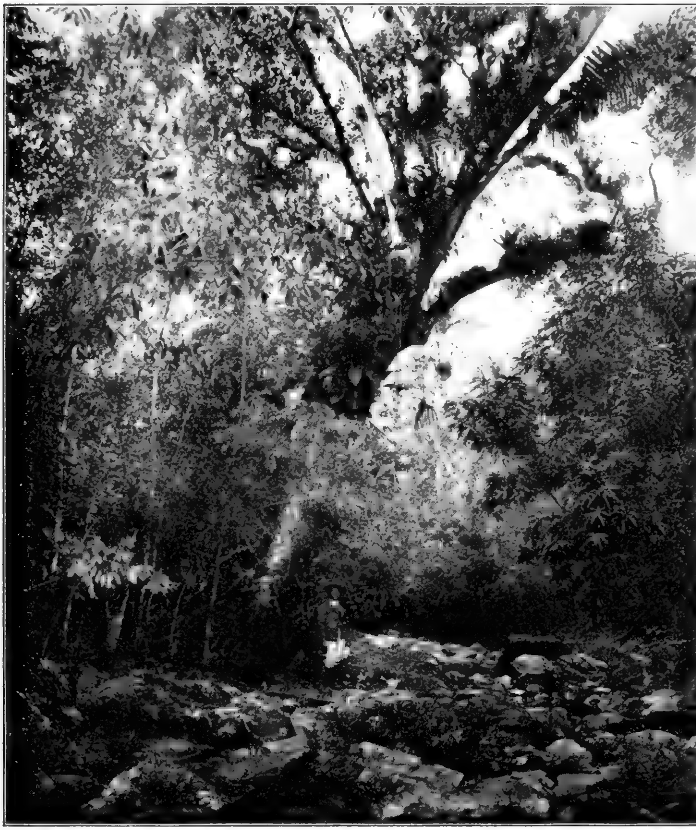

Fig. 2. Dense vegetation as seen in a tropical forest

During the relatively dry season, water may cease flowing in the stream bed here shown, but even then almost all available space is occupied by plants. During wet seasons in such regions plants often grow upon one another in quantities that break down the supporting stems

domesticated plants have been derived from wild ancestors. Many of these have been improved, until now their products are of much better quality or quantity than in their wild

condition. In the case of some of these domesticated plants — for example, wheat — it is possible that a single wild plant may have produced as much and as good wheat as one cultivated plant does now, but in most cases, doubtless, great improvements have been made, and in all cases the total product has been vastly increased. The northwestern United States produces wheat that is of great importance to the welfare of the nation. In the corn belt of the central United States there are seven states that produce nearly half the corn used in the whole world — an amount that is ordinarily worth annually almost three billion dollars. The cotton crop of the Southern states (three fifths of the cotton of the world), together with cotton-seed products, is worth annually nearly one billion dollars.

3. Plants are everywhere. Cultivated plants constitute only a very small part of the plant population of the earth. In fact, we are so accustomed to seeing plant life on every hand that we ordinarily think little about it. Most people have never been in surroundings where plant life is not fairly abundant. The upper parts of the cones of active volcanoes and the interiors of their craters, a few mud volcanoes and hot springs, the exposed surfaces of arctic ice fields or of glaciers, together with a few poisonous alkali tracts, are almost the only parts of the earth's surface on which or in which plant life is not present. There are, however, very great differences in the density of the plant population of different regions. Many deserts have only here and there a shrub or other plant capable of enduring the inhospitable soil and climatic conditions there encountered. In the sand hills which are found along the Great Lakes (fig. 1), along the shores of the Atlantic Ocean, and elsewhere few plants are able to grow. On the other hand, a weedy garden, a grass lawn, or a meadow usually has hundreds of plants to every square yard of surface, and tropical forests often present a tangled mass of vegetation (fig. 2) towering up to a height of nearly two hundred feet, interlaced with climbing plants, sometimes hundreds of feet

in length. Some very pure natural waters contain no plants readily visible to the eye, while the foul drainage of a barnyard in warm weather may be of a uniform bright-green color from the presence of many thousands of microscopic plants in every drop of the water. Plants occur in all the seas as well as in all the fresh waters, on every kind of soil from the wettest swamps to arid deserts, on rocky cliffs, and on branches and leaves of trees.

4. Structures and habits of plants. Although the relations of plants to human life and the life of the lower animals are of the highest importance, it is not this aspect of botany which is of largest concern to the beginner. We have no reason to suppose that plants exist for the benefit of man. Plant structures and processes are of importance primarily in maintaining the life of plants themselves, and their use by men is a by-product of plant life. In order to gain any scientific knowledge of elementary botany, it is necessary to try to find out what are the forms and internal structures of plants, how they carry on their life processes, and what relations exist between them and the external conditions of soil and climate. To these studies may be added some consideration of the relations between the plant and its plant and animal neighbors, and other studies about what plants have done for man and what he is trying to do with plants. But it must be clearly understood that the study of plant structures and functions — what plants are and how they live — is fundamental to any other study of plants.

CHAPTER II

THE PLANT AS A WORKING MACHINE[1]

5. The parts of the plant. Ordinary plants are composed of roots, stems, leaves, flowers, and seeds. Not infrequently some of these parts may be absent, or they may be so unusual in form and appearance that their nature is not readily seen. Thus, it is not usually evident to others than botanists (1) that an onion bulb consists of a very short stem and thick, broad leaves, and that when the onion grows, the roots descend from the lower part of the stem and green leaves and a flower-bearing stem arise from the upper end of the stem within the bulb; (2) or that in plants such as turnips and carrots the stem and root are not definitely set apart from one another; (3) or that the flowers of oak and elm trees, so very unlike flowers as we commonly think of them, have nevertheless as good a right to the name as has the flower of an apple tree.

The five parts of a common plant together constitute a well-organized unit (fig. 3). The parts differ from one another in structure, in form, and in what they do, but the successful work of each part contributes to the successful work of the whole plant. Although we may often be more interested in what is being done than in the mechanism which does the work, we cannot understand plant work except as we give constant attention to the structures of the parts of plants.

[1] This chapter gives an outline of plant structure and plant work. It does not present details, but gives a general idea of the nature and functions of the plant. If this outline is presented briefly, it serves to interpret the more detailed work of later chapters much more profitably than if numerous details are presented first. The chapter should be read carefully by every member of the class and discussed in one or two recitations, or it may be read and discussed by pupils and teacher together.

6. The work of plants. Plants must have materials for their nutrition just as truly as animals do. It does not follow, however, that the same kinds of food material are needed or that they are secured or handled in ways that correspond to those found among animals. As a rule, animals eat plants or animals that have used plants as food. Occasionally, as we shall see later, seed plants may use animals as food material, and it is generally known that such plants as bacteria and molds may live upon animals. Green plants may secure water and carbon dioxide, and from them they may make foods, such as sugar and starch. They may use these as food or may combine them with other substances and thus make foods, such as proteins, that are more complex than sugar and starch. It is also one of the conspicuous and important facts of plant life that much surplus plant food is stored in grains and fruits, and this stored food may serve as nutrient material for man and the lower animals. Indeed, many people find that their chief interest in plant life is due to the possibility of securing and using this surplus stored plant food as found in such things as the grains

FIG. 3. An indian-corn plant with roots, stem, leaves, and flowers

Two kinds of flowers are formed, one in the ear (*e*), from which the silk (*s*) protrudes, and the other in the tassel at the tip of the plant. Special brace roots (*b.r*) are sometimes formed

of corn, wheat, and oats, in the vegetables and fruits, and in the oil of corn and cotton. It must also be noted that many tissues or fibers of great significance — such as cotton,

Fig. 4. A red-oak tree whose roots have lost their anchorage through removal of the soil by water

Compare the position of the tree with that of the beech and other trees in the background

hemp, flax, and the timbers of commerce — are produced in connection with the ordinary processes by means of which plants manufacture plant foods and use them in their growth.

7. Roots. In places such as very steep hillsides or along river banks one may often see plants whose roots have been uncovered by removal of the soil in which they grew. When the soil is removed, the roots sooner or later are unable to hold the rest of the plant in place, and it may fall to the ground (fig. 4). When their roots are partially uncovered, trees that have withstood heavy winds for years may succumb to winds that are less severe than many which they had previously been able to withstand. In cultivated hilly fields heavy rains often erode the soil from above the roots to an extent that allows the plants to fall. Obviously one function served by roots is that of holding plants in place; this is called *anchorage*.

But oftentimes one may observe plants whose roots are partially uncovered, the plant still erect in position but wilting or with yellow leaves and evidently not growing well. Furthermore, in some cases the roots on one side have been uncovered and the plant has fallen, but its branches and leaves are still in a thrifty condition. If all or nearly all the roots are exposed, or if the soil is extremely dry, the water supply of the plant, which comes through the roots, is interfered with, and because of a shortage of water the leaves may wilt; but if a part of the roots are still well imbedded in moist soil, though the stem and branches may have fallen, a fairly adequate supply of water may still reach the stem and leaves, and wilting and death may not follow. Roots, therefore, serve not only for anchorage but also as structures through which the plant receives its water supply, that is, as organs of *water absorption*.

8. Rootlets and root hairs. In examining the root system of any common plant (fig. 3) it is usually seen that the roots directly joined to the stem are relatively few and large, and that they divide and redivide until extremely fine rootlets are formed. In most plants the larger roots are covered by bark, through which water does not pass readily. Even rather small root branches are covered with root bark. But the smallest

and terminal rootlets have no bark, and from their surfaces there grow very fine tubular threads known as *root hairs* (figs. 5 and 6). Root hairs have extremely thin walls, through which water from the soil can pass into the interior; thence it passes upward through rootlets and larger roots, through the stem and into the leaves. Substances that are in solution in the soil water may be transferred into the plant through the delicate walls of the root hairs and their lining. Root hairs do not grow over all the surface of the terminal rootlets, but develop a little way from the root tip. They do not live very long, the older ones constantly dying. Thus, as the root tip grows forward through the soil the actual number of root hairs on a rootlet may remain practically constant during the growing season, on account of the dying of older root hairs and the development of new ones near the root tip on the new growth of the rootlet. It is evident that the area of root hairs advances, although no individual root hairs move forward through the soil. Although extremely delicate in structure, root hairs grow between and around the hard particles of soil (fig. 6). It is easy to count the root hairs on a small portion of the root. Corn rootlets grown in damp air have been found to bear 425 root hairs on an area $\frac{1}{25}$ inch square. The large number of rootlets and the enormous number of root hairs serve to make a network which completely permeates the soil in the region of the rootlets. The root hairs are the chief organs by which water and substances in solution in water are absorbed from the soil.

FIG. 5. A mustard seedling grown in a band of filter paper inside a drinking glass, so as to show the root hairs

Note the difference in length and condition of the root hairs on the different parts of the root

9. Stems as supporting structures. In an examination of the stem of almost any woody plant there appears an outer dead bark, an inner green bark, a cylinder of wood, and sometimes a small area of pith in the center of the woody cylinder. Although some of our commonest agricultural plants, as corn and wheat, do not have a central woody cylinder, they have an outer region of very hard, strong tissue, and either a hollow central region, as in the wheat, or a large pithy center through which run a number of fibrous bundles, as in corn (fig. 7). In wheat the fibrous bundles lie close to the hard outer portion of the stem; consequently they are not seen nearly so easily as are the fibrous bundles in corn. A stem could not stand alone in an upright position if it did not possess some such rigid tissues as those generally noted in woody plants or in the outer portions of corn and wheat stems. Other factors that help in maintaining an upright position of the

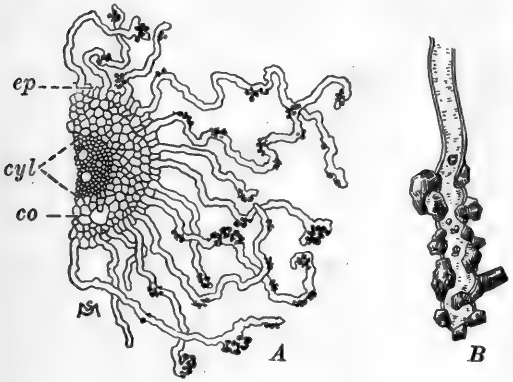

FIG. 6. Root hairs

A, a cross section of a root, showing the central cylinder (*cyl*), the cortex (*co*), and the epidermis (*ep*), with root hairs that have grown from epidermal cells. *B*, a root hair enlarged to show the soil particles attached to it

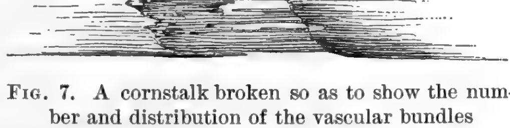

FIG. 7. A cornstalk broken so as to show the number and distribution of the vascular bundles

stem will be discussed in later chapters. By means of their upright position, stems may support the branches and leaves in such a way that they are upheld in the air. *Support* is evidently one of the conspicuous functions served by plant stems.

Many plants live for only one year (*annuals*) or two years (*biennials*); in such plants large and strong stems are not often found. Other kinds of plants may live for two or more years (*perennials*). Woody perennials may live for hundreds of years, and their stems usually increase in thickness from year to year, until, in the case of trees, stems are sometimes developed which are several feet in thickness, much over a hundred feet in height, and of such strength that very heavy tops are upheld throughout the severest storms. The increase in thickness is shown by the *annual rings* of wood (fig. 8). Often the age of a woody stem may be indicated approximately by its annual rings, but that these are not always truly annual rings is shown by the fact that when there are intermittent favorable and unfavorable growing periods within the same season, more than one ring may be formed within one year. Cases are known of young trees that have almost twice as many rings as the number of years of their age.

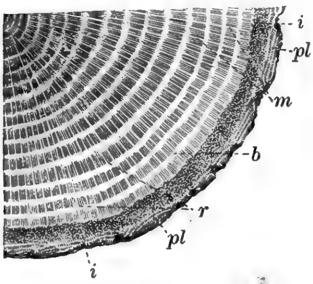

FIG. 8. One quarter of a cross section of a stick of oak wood

m, medullary rays, running from bark to pith; *r*, annual rings; *b*, boundaries between rings, porous from presence of many ducts; *i*, interior fibrous layers of dead bark; *pl*, hard plates of dead bark, splitting away from each other but attached to bark beneath. Reduced

10. Stems as passageways for liquids. When the stem of an actively growing plant is cut, water sometimes exudes upon the cut surface of the stump. The same outpouring of water is seen when a leaf of a corn plant is peeled away from the stalk. When we wish to keep cut flowers in a fresh condition, we place their stems in water. If we should place a fresh leaf of celery in a solution of one of the aniline dyes

and let it remain for a few minutes, and then remove it and examine it by sectioning, definitely stained regions would be seen, other regions being unstained, thus showing not only that the liquid passed upward through the leafstalk, but that it passed through certain tissues of the stalk. If a leafstalk of celery is carefully broken and one part pulled slowly away from the other, there are seen fibers, or threads, which are quite like those shown in the cornstalk (fig. 7). These threads are known as *fibrovascular bundles*, which means simply "collections of thread-like tubes." It is through these fibrovascular bundles that water and substances in solution in water pass from the soil through roots, through stems, and into leaves. Through them also plant foods may pass from leaves downward through the plant. Indeed, there are certain parts of each bundle through which water passes upward, and other parts through which the organized plant foods are carried. The fibrovascular bundles, therefore, are the chief transportation lines of the plant.

11. Leaves. Most leaves are expanded so that they expose much more surface than would stems of equal weight. In some cases (fig. 3) the entire leaf is expanded, while in others there is a leafstalk, or *petiole*, and the expanded portion, the *blade*. The leaf blade may be single (*simple*) or sub-divided (*compound*). From the plant stem the fibrovascular bundles extend into the leaf, where they are known as the *veins* of the leaf. They terminate in the leaf, sometimes in its tip and sometimes in the margin as well as in the tip. Water from the soil may therefore pass through the fibrovascular bundles of the roots, the stem, and the leaves, into the interior of the leaf. From the leaf some of this water is evaporated into the air.

Part of the water in the leaf, instead of being evaporated into the air, is used in the construction of plant food by means of a process which is of very great importance to all living things. Carbon dioxide from the air enters the leaf through its surface. The leaf is green because of the presence of a

coloring substance known as *chlorophyll.* When the sun shines upon the leaf, the chlorophyll absorbs energy from the sun's rays. This energy serves to decompose the water and carbon dioxide. The products of this decomposition immediately reunite, but into new substances, which, after several chemical changes, may become sugar or starch. Sugar and starch may be used as food by the leaf, or be carried to other parts of the plant and used, or be made into more complex foods, as oils or protein foods. It is from foods that plants as well as animals derive the energy that makes activity, growth, and life itself possible.

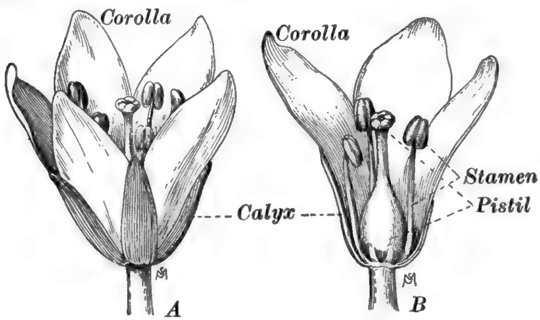

Fig. 9. Diagrams of two flowers

A, entire flower; *B*, flower with part of the floral structures removed

Since water and carbon dioxide, the substances from which a green plant thus manufactures food, are substances that are not ordinarily regarded as foods for other living things, this process is far-reaching in its significance. The storage of surplus plant food in seeds (fig. 12), roots, stems, and leaves is also most significant, since our food and many of our industries depend upon this surplus material.

12. The flower. In addition to the roots, stems, and leaves, flowers are often conspicuous parts of plants. They are the structures by means of which seeds are produced. In some plants but one kind of flower is produced (fig. 9); in others two kinds are formed (figs. 10 and 11). In such a flower as that shown in figure 9 the outermost and lowest floral parts form the *calyx*, each part being a *sepal;* the parts next above the calyx constitute the *corolla*, each part being a *petal;* above

the corolla are the *stamens;* and at the center of the flower is the *pistil.* Within the enlarged stamen tip, or *anther*, are many grains of *pollen*, and within the swollen basal part of the pistil (the *ovary*) are one or more *ovules.* The ovules are the developing seeds.

In such plants as indian corn and other members of the grass family, to which corn belongs, *staminate* (stamen-bearing) flowers are often found on one part of the plant and

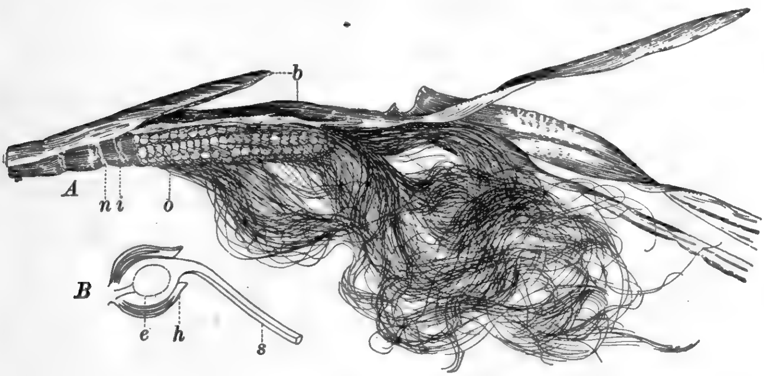

FIG. 10. A young ear of sweet corn

A, entire ear, showing the joints, or nodes (*n*), and the internodes (*i*) of the branch which bears the ear; the leaf-like bracts (*b*) which inclose the ear, and the grain, or ovary (*o*), to each of which one of the silks is attached. *B*, an enlarged diagram of one grain, showing the embryo sac (*e*), the inclosing husk, or chaff (*h*), and the silk (*s*)

pistillate (pistil-bearing) flowers on another part (figs. 10 and 11). In corn the staminate flowers are known collectively as the tassel, and the pistillate flowers collectively as the ear. Each staminate flower consists of a simple leaf-like bract which incloses three stamens. The amount of pollen borne by a single tassel is very great; it is estimated by one authority [1] that from 20,000,000 to 50,000,000 pollen grains have been borne by a single corn plant. A single pistillate flower consists of a short and obscure *bract* (often called

[1] DeVries, Plant Breeding. The Open Court Publishing Company, 1907.

chaff) and an ovule with an elongated *style* (called *silk* in corn), which grows attached to the ovule's tip. The tip of the style, or silk, is the *stigma*, which is the roughened, sticky surface to which pollen grains may adhere when they fall upon it.

13. The seed. From a pollen grain which has fallen on the stigma there grows downward through the style a very small

FIG. 11. Two branches from the tassel bearing staminate flowers

tube (the pollen tube), which finally reaches the interior of the ovule, where there is a very small egg. This egg is fertilized by its union with a smaller body carried by the pollen tube, and from the result of this fertilization a new embryo corn plant develops within the ovule. While still within the developing ovule, or seed, this young plant produces its root tip and stem tip; in corn and other grass seeds there is a special structure (scutellum) by means of which the embryo

plant absorbs food material from the ovule. While the embryo plant is developing, food material is constantly being transported into the grain, or ovule, until finally a relatively large amount of food material is thus deposited (fig. 12). The ripened seed, or grain, consists of the old ovule wall, the stored food material, and the embryo corn plant. The scale-like bract, or chaff, which surrounded the young ovule, often adheres to the ripened grain. In many kinds of plants

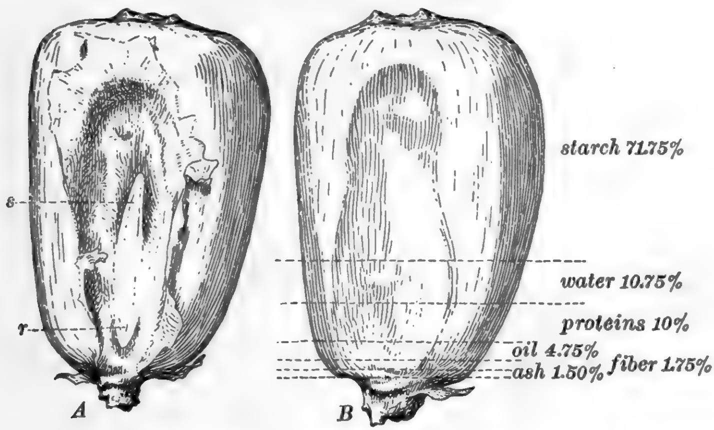

FIG. 12. Grains of indian corn

A, a grain with seed-covering partly torn away, showing the root tip (*r*) and the stem tip (*s*) of the embryo corn plant within the seed. *B*, a grain showing the percentage of different substances that compose it

the ripened seed or seeds may be surrounded by one or more structures, the whole then composing the so-called fruit.

14. Seed germination. Seeds may lie dormant for a very long time or may grow soon after being formed. Under favorable conditions the young plant within the seed bursts the seed coat and continues its growth as a new plant. It pushes out its root, stem, and leaves and soon assumes the appearance of the kind of plant that formed it (figs. 13 and 14). In some kinds of plants, when the seed germinates, the seed coat remains underground and the stem and leaves grow

upward from it; in others the seed coat is carried upon the seed leaves until they appear above the surface of the ground, when by the spreading of the seed leaves the coat is dropped (fig. 13). Some kinds of plants have one seed leaf, as in corn; while others, as the sunflower, have two seed leaves, between which the first true leaves appear.

15. Further study of the parts of a plant. It must be evident from the discussion in this chapter that a plant is

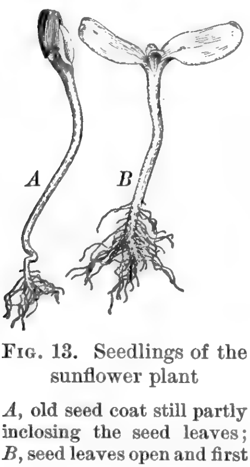

FIG. 13. Seedlings of the sunflower plant

A, old seed coat still partly inclosing the seed leaves; *B*, seed leaves open and first true leaves appearing

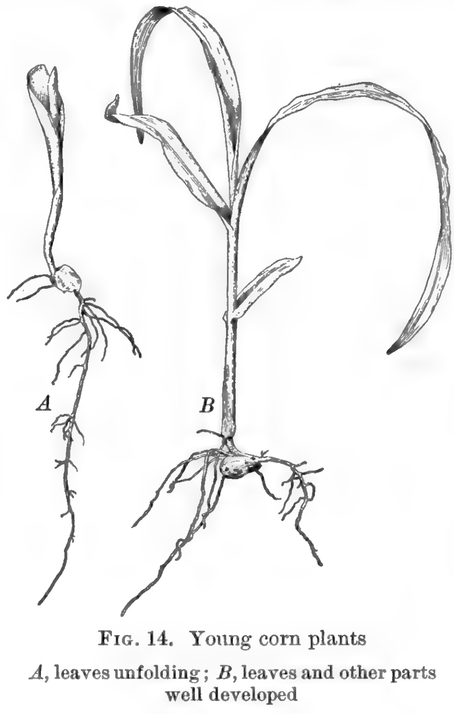

FIG. 14. Young corn plants

A, leaves unfolding; *B*, leaves and other parts well developed

a sort of machine consisting of roots, stem, leaves, flowers, and seeds. By means of this plant machine raw materials are secured and manufactured into plant food. This manufactured food is distributed through the plant; some of it is used immediately and some of it is stored. Seeds are manufactured, and by means of them new plants are started on their round of activities. Having in this chapter merely outlined the nature of the plant machine and the work done by

it, we must now consider in greater detail the special features of each part as these are shown by more careful study of their structures and work. Succeeding chapters will deal with these matters, but to see clearly the significance of special structures and functions this unit outline of the whole plant and its work should be kept constantly in mind. The student can come to an understanding of the life of the plant only by observing how its organs coöperate in the processes of nutrition, growth, and reproduction. It has been the purpose of this chapter to give an outline of the whole plant; to raise questions concerning what a plant is and how it works; and to suggest, in a general way, the answers to these questions. Such a general view of the nature of a plant furnishes the best basis for further study.

CHAPTER III

ROOTS AND THEIR RELATION TO THE WORK OF PLANTS

16. Structure of roots. We have already discussed the general nature of roots. Careful examination of a cross section of a young root shows that there is a definitely organized *central cylinder*, around which is the *cortex*, both well shown in figure 15. The surface layer of the cortex is the *epidermis* (fig. 16, *e*). The growing root tip is covered with several layers of dead or dying cells, which make up the *rootcap*. As the root pushes its way through the soil the rootcap is constantly being worn away on the outside. During the seasons of activity the rootcap is continually being rebuilt by the formation of new layers of cells on its inner surface. In older roots the epidermis has given place to *bark*, which is composed of several layers of cells. If a cross section of a very young root of a dicotyledonous plant is examined with a moderate magnification, it will be seen that the cortex is made up of rather loosely aggregated cells, while the central cylinder is more closely compacted. In the cylinder are found a definite number of radially arranged fibrovascular bundles. The woody strands of these bundles alternate with strands of what are known as *bast fibers*, shown in figure 44.

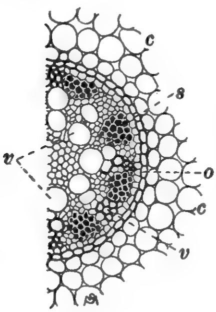

FIG. 15. Cross section of central portion of root of sweet flag (*Acorus*)

c, cortex; *o*, outermost layer of cells of central cylinder; *v*, vessels of various sizes; *s*, sieve cells. Magnified 70 diameters. After De Bary

17. The root-hair cell. The general tubular structure of root hairs was very briefly explained in section 8. A root hair,

together with the minute sub-division of the epidermis from which it springs (fig. 16, *e*), furnishes a good example of one kind of plant cell.[1] Each live root hair consists of an extremely thin sac, the *cell wall* (shown in figs. 6 and 16 merely as a continuous line bounding the root hairs), and the living contents of the cell, known as the *protoplast*. The cell wall consists of a material known as *cellulose*, familiar to all in the microscopic fibers of cotton. The cell contents, or protoplast, of a root hair consists largely of a nearly transparent portion, the *cytoplasm*, composed of nitrogenous material which may be roughly compared to very thin white of egg. Within the cytoplasm are found many somewhat opaque and very minute particles, also rather large, clear spaces consisting of very watery cell sap, and a structure less transparent than the cytoplasm, known as the *nucleus* (fig. 16, *n*).

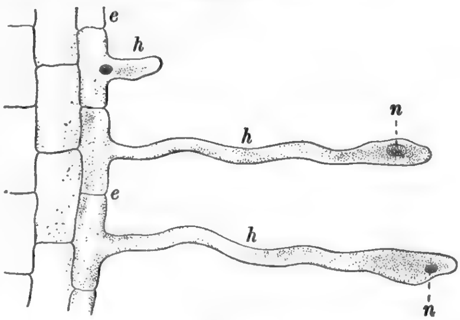

FIG. 16. Cells from the surface of a young rootlet

Showing epidermal cells (*e*) and one young and two older root hairs (*h*). In the root hairs the nucleus (*n*) and granular cytoplasm of the cells are shown. Greatly magnified. After Bonnier and Sablon

Other cells, of more complicated constitution than root hairs, often contain many other structures and materials besides those here mentioned. Some of these are briefly discussed and figured in Chapter IV.

18. The work of cells. The simplest plants, as will be shown later, consist of a single cell each. Every ordinary flowering

[1] The student will find many illustrations of different types of cells in later chapters. Some very simple ones are discussed in Chapter XV. Many cells of the lower forms of plant life are much more easily studied than the colorless and nearly transparent root hairs. The minute anatomy of the cell is most easily studied in cells which exist as separate individuals and which have among their contents some colored structures.

plant consists of hundreds of thousands or millions of coöperating cells, which together carry on the work of the plant.

The root-hair cell shows its life most clearly by growing and making its way around obstacles (fig. 6). Other plant cells often give much more striking evidence of life in the movements which are executed by single cells or by organs built up of great numbers of cells. Many such movements will be described in subsequent chapters. In this place it is sufficient to call the student's attention to the fact that the protoplast is alive in just the same sense that any minute animal is alive. Whatever any living organism can do it does by virtue of the energy of its protoplasts.

The most remarkable and peculiar of the characteristics of protoplasm are due to its possessing *irritability*. By this is meant the power to respond in some definite way to any suitable *stimulus*, or exciting cause, acting from within or without the plant body. Some of the principal stimuli are gravity, heat, light, chemical substances, and contact with solid objects. When protoplasts, either singly or combined into some organ of the plant, are acted upon by any stimulus to which they are sensitive, there is usually no immediate visible response. If, for example, a young seedling with a stout taproot is pinned horizontally to a piece of cork which lines the vertical side of a glass jar containing moist air, no change is at first noticed. In a few hours, however, the part of the root for a short distance back of the tip will be found bending vertically downward. This movement is a response to the stimulus of gravity, acting upon the very sensitive young root and causing unequal growth in the upper and lower sides. It is not a mere bending, like that of an unsupported piece of wet string, for the moving end-portion of the root will be found to push downward with a force of more than ten times its own weight.

19. Turgidity. Root hairs and other cells of plants usually take up water until the cell walls are distended with water and protoplasm. The outward pressure which distends and stretches the walls is called *turgor*, and the resulting condition

is called *turgidity.* Turgor doubtless helps to force water upward through the stem. The distention of cells due to turgor also accounts for the rigid or erect position of most leaves, growing shoots, and succulent stems. Each distended cell, like an inflated balloon, assumes a semi-rigid position, and a mass of distended cells pressing against one another makes the whole

Fig. 17. A young cucumber plant (grown in a flowerpot)

At left, in normal condition; at right, much wilted from having been left unwatered for several days

structure rigid. But just as, when the air escapes from a balloon, its wall collapses of its own weight, so the cells of the leaves and shoots collapse when, on account of loss of water, they lose their turgidity. When soil water is not available to the plant, the outgo from the leaves is often greater than the income from the roots, and in such cases wilting follows (fig. 17). If water does not again become available, the plant will die, but with a renewed supply turgidity and the resulting rigidity soon return.

20. Amount of water pressure in woody plants. When very little water is being lost by evaporation from the leaves, the sap pressure in trees and large shrubs is often great. As a result of this pressure, in early spring sap escapes freely from cuts or borings made into the roots, trunks, or branches of many kinds of trees and shrubs. The "bleeding" of grapevines pruned too late in the season is familiar to many people, as is also the flow of sap from sugar maples. Woody plants cut off near the root may have a pressure gauge of any convenient sort attached to the cut surface, and the pressure can thus be measured with accuracy. A severed grapevine has been found to exert a pressure sufficient to sustain a column of water more than 43 feet high, and the root of a black birch tree a pressure equivalent to about 86 feet of water.

In the tallest trees, the giant redwoods and the Australian gum trees (*Sequoia*, *Eucalyptus*), water is sometimes raised to a height of from 300 to 400 feet. It is not yet known how large a part of the force required for this is due to the pressure with which the sap from the roots is impelled up into the stem, nor what other causes are mainly responsible for the rise of water into the highest portions of the tree.

21. What roots do for the plant. All plants must have water, at any rate during the part of their lives when they are actively manufacturing plant food, and it is by means of their roots that most familiar plants absorb water and the substances that are dissolved in it. Yet absorption of water is not the only function of roots. They often absorb oxygen; they commonly serve to anchor the plant; they may aid it to climb; they frequently store food, water, or both; and in or on them are sometimes carried on important chemical operations which result in gaining material for the production of plant food. Many kinds of roots reproduce the plant; that is, a root or part of one may grow into a new individual plant like the one to which the root belonged.

The great importance of roots to life and growth is well shown by the results which follow from any severe injury to

the root system. Cut off most of the roots of a tree and it will die for lack of water. On the other hand, many (though not all) kinds of trees may be cut down nearly level with the ground and still survive, the stump throwing up a vigorous crop of sprouts, which grow into saplings that eventually replace the fallen trunk.

The necessity of roots for anchorage is well shown by figure 4. In many cases the power of the roots to hold trees upright is greatly increased by the formation of buttresses of wood, which extend for some distance up the trunk from the origins of the larger roots. In some large tropical trees these buttresses attain enormous dimensions.

22. Earth roots; direction and extent of root system. The roots of most common flowering plants in temperate regions are *earth roots;* that is, they grow in and through the soil. The nature of the soil greatly influences the extent and position of the root system. Sandy soils favor the development of an extensive root system, while clay soils do not. If the good soil forms only a shallow layer over shale or sterile clay (or in the arctic regions over ice), the roots spread out in a flat, mat-like fashion.

The smaller rootlets are so woven through the soil that it is never possible to unravel the entire root system. The roots of a single oat plant, if arranged in a straight line, have been found to measure over 450 feet in length. Desert shrubs sometimes send their roots down as much as 60 feet toward the water supply. In parts of California it has been found that common farm plants, such as alfalfa and wheat, may have roots reaching moist earth at a depth of from 13 to 15 feet.

Why is deep plowing between hills of half-grown corn likely to injure the crop?

23. Pull of roots due to shortening. Frequently rootlets or the taproots of herbaceous plants shorten after they are fully grown. This shortening has a tendency to pull the stem and leaves of the plant downward. It is interesting to notice how some plants with rosettes of leaves, like chicory, dandelion,

and fall dandelion, pull their rosettes down tightly against the surface of a lawn, kill the surrounding grass, and thus secure for themselves a little clear space in which to grow.

24. Effects of roots on the soil. If we dig up a spadeful of earth from a well-grassed meadow or from a little inside the circumference of the circle formed by the roots of a tree, we shall find the soil bound together by the living roots or full

FIG. 18. Cypress trees (*Taxodium*) growing in a swamp

The conical "knees" growing from the roots and nearly always above water are thought to serve as channels to supply air to the roots

of little, crooked, tubular channels left by the decay of dead ones. Thus the soil is in the one case held together so as to prevent its becoming gullied and washed away by rains, and in the other case made more porous and more easily penetrated by air and water. The latter effect is a very important one in the case of stiff clay soils, which, when closely packed, are almost waterproof.

The extensive washing away of soils when they are unprotected by a covering of plants, such as grass, shrubs, or forest

growth, is one of the most serious calamities that can befall a country. It is especially formidable in hilly regions, which may become wholly uninhabitable if the forests are cut off and the turf on the hillsides is destroyed by too constant grazing and trampling of sheep or goats. Throughout southern Europe immense areas of land once valuable for timber and for grazing have thus been ruined, and the same process is under way in our own country all the way from New England to the Pacific coast region. One of the clearest ways in which the idea of loss by the washing away of the soil can be presented is by considering how the land is carried into the sea by great rivers. The delta of the Mississippi covers an area of more than 12,000 square miles. It consists of material brought down by the river in the form of mud, which now forms a deposit of unknown thickness, probably averaging more than 500 feet. It is calculated that the river carries every year enough solid matter to form a layer one foot thick over an area of about 268 square miles. Remembering that this mud consists mainly of the choicest part of the rich soil of the Mississippi basin, it is easy to see that the land is robbed every year of the material to support enormous harvests[1] (see Chapter XIX).

25. Air supply of earth roots. Earth roots require a considerable supply of air. This is shown by the fact that most trees are injured or killed when the soil in which they grow is long flooded with water, as is often the case when a stream is greatly widened by the construction of a dam across it. The same result is seen when low fields of corn, wheat, oats, or cotton are flooded after heavy rains. Unglazed earthen flowerpots are better for house plants than glazed ones or glass jars, because they allow air to pass freely through the porous material of the pot.

How do the earth roots of such plants as water lilies get their air supply?

[1] See "Forest Influences," *Bulletin No. 7*, Division of Forestry, U.S. Dept. Agr., 1893.

Sandy soils contain more abundant air spaces than compact clays, and in clayey regions one important reason for deep and thorough cultivation of the soil is to insure the free access of air to the roots of crops.

FIG. 19. Effect of deficient water supply on growth

The plant is groundsel, a common European weed which grows to from 12 to 18 inches high. At *D* is shown the relative height of the same plant when grown in very dry sands along Mediterranean beaches. Modified after "Flora Danica"

26. Water supply of earth roots. It is known to most people that ordinary plants must absorb through their roots a good deal of water. If house plants are left unwatered for two or three days, they begin to wilt. Field crops and sometimes even shade trees do the same in times of severe drought. Many plants, when grown in dry ground, will flower and seed in a dwarfed condition. The common groundsel, a weed not infrequently found in long-tilled fields and about dooryards (fig. 19), under favorable conditions grows to be a foot or more in height, but in the very dry sand along Mediterranean beaches this plant flowers and seeds when only an inch high.

27. Roots of desert plants. The plants of desert and other dry regions frequently show striking peculiarities of form and structure, and among these is an unusual development of the root system. Plants able to live under extremely dry conditions are known as *xerophytes*. Familiar examples of these are century plants and cacti. Some xerophytes, as the cacti, have a rather widely spreading root system extending quite near the surface of the earth; such a root system makes the most of every one of the infrequent

FIG. 20. A desert *Pelargonium* (closely related to the common so-called geraniums)

Note the scanty leaf surface and the fleshy root and base of the stem, containing much water and reserve food. After Andrews

rainfalls of the regions where these plants grow. Others, as the mesquite of the extreme southwest, have roots that penetrate into the earth to extraordinary depths until they reach moist soil. Still others — for example, many South African plants (fig. 20), some wild morning-glories, and the big-root[1] of the Pacific coast — have fleshy roots in which much water is stored.

28. Water roots. Most aquatic perennials, like the cat-tails, arrowheads, pickerel weeds, pond lilies, and many grasses and sedges, form mainly earth roots. On the other hand, some plants not aquatics — for example, many willows — can develop roots indifferently either in earth or in water. Willows growing along a brook usually send great numbers of roots into the earth, and also produce a multitude of fibrous roots which dangle in the water. Cuttings of Wandering Jew (*Zebrina*), geranium (*Pelargonium*), and many

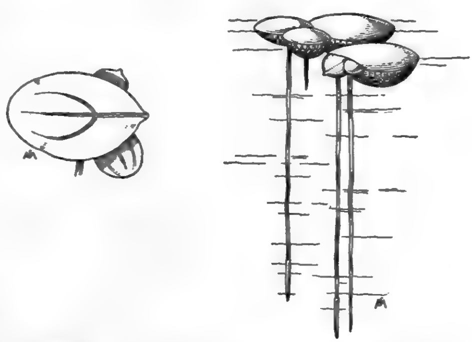

FIG. 21. Duckweed, a floating aquatic plant

At left, top view of single plant 8 times natural size; at right, group of three individuals of another species represented as floating, with roots hanging vertically. Three and one-half times natural size. After Prantl

[1] *Echinocystis*.

other common plants root readily in water and grow for a long time if supplied only with ordinary river or well water. The number of kinds of seed plants which float, and therefore

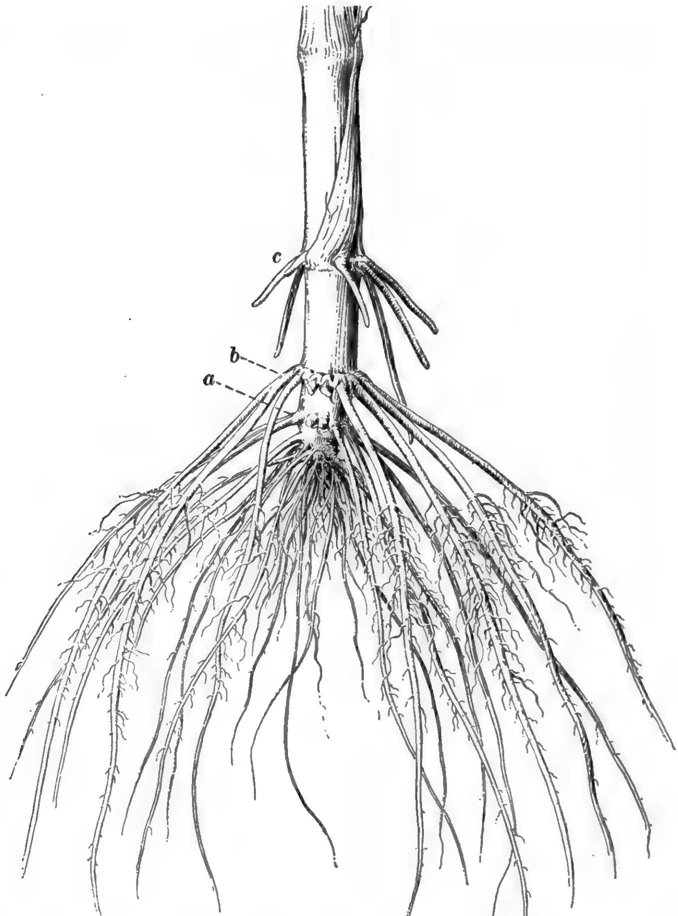

FIG. 22. Aërial roots (brace roots) of corn. Reduced

Note that the series *a* and *b* began as aërial roots, but later entered the ground and then developed many small branches. Those at *c*, if not checked by frost, would eventually also have reached the ground

produce only water roots (if they have roots at all), is rather small. Some of the commonest are the so-called water hyacinth and the little duckweeds (fig. 21).

Plants like the pondweeds, water crowfoot, water weed (*Elodea*), and others, which grow entirely submerged, do not need an extensive root system, as they are in no danger of drying and so use their roots mainly for anchorage.

29. Air roots. Many plants which root in the earth, such as corn, poison ivy, and English ivy, produce roots from portions of the stem aboveground. These are called *aërial* roots. In some cases, as in corn (fig. 22) and in the mangrove tree, which grows along tropical coasts, the aërial roots finally reach the earth and serve as braces to prop the stem of the plant upright. In other instances the roots never reach the ground, and then they may serve to enable the plant to climb, as in the case of the poison ivy and the English ivy, or they may serve to anchor the plant to stones or to the bark of trees and at the same time to absorb rain water or dew. Many tropical *air plants* are perched on the bark of trees, or even on their leaves, and get their water supply from dangling aërial roots which are covered with a layer of absorbent bark that catches water and then gradually gives it to the plant.

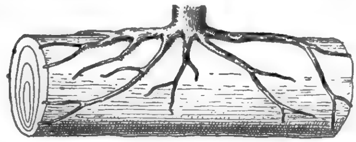

FIG. 23. Base of stem and sucking roots of the mistletoe, growing on an apple branch

In the figure the bark of the branch has been removed so as to show how the mistletoe roots spread between the bark and the wood of the host plant. In the section of the branch at the left is shown the way in which short portions of the mistletoe root penetrate into the wood of the host. One half natural size. After Bonnier and Sablon

30. Parasitic roots. Certain plants, such as the dodders (fig. 34) and many kinds of mistletoe (figs. 23 and 35), live wholly or partly at the expense of other plants, into which their sucking roots, or *haustoria*, penetrate, sometimes very deeply. The mode of life of such parasites will be further discussed in Chapter IV.

31. Reproduction by means of roots. Roots are often capable of producing buds which may develop into new individuals and thus propagate the plant. The sweet potato is a good instance of this, each root, if buried in moist sand, being capable of giving rise to several new plants (fig. 24). Roses are propagated by root cuttings, and some trees, such as the silver-leaved poplar (*Populus*) and the black locust (*Robinia*), are very troublesome because of the readiness with which young sprouts (sometimes called suckers) spring up from the roots. A considerable colony of these young sprouts may often be seen quite surrounding the parent tree and extending many feet away from it. Many bad weeds, such as the field sorrel (*Rumex*) and the Canada thistle (*Cirsium*), are reproduced by roots. In case of desirable plants that can be propagated either by pieces of root or by seeds, it is generally better to use root cuttings, as they will grow much faster.

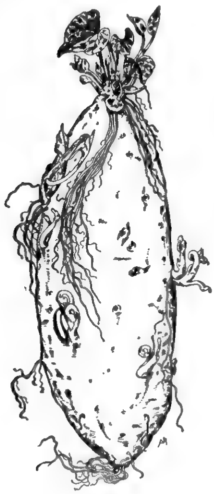

FIG. 24. Vegetative reproduction of the sweet potato

The potato was buried in moist sand and began to sprout, that is, to send out shoots from adventitious buds at various points. Each shoot may grow into a new plant. About half natural size

Among plants that you know, are there more instances of useful or of injurious kinds that are usually propagated by the root? Give examples.

PROBLEMS

1. When actively growing stems are cut off, do they "bleed" on both the upper and the lower cut surfaces? Why?

2. How could an experiment be made to show the exact amount of upward pull and of lateral pull which the anchorage of a plant will resist?

3. What practical advantage is taken of the powerful anchorage of shade trees?

4. Why must swamps be drained before most crops can be grown in them?

5. What kinds of plants would be useful in preventing the drifting of sand in dunes like those of figure 1?

6. What are some reasons why embankments, as of reservoirs and railroad rights of way, should be kept well grassed over?

7. Just where would you place soil fertilizers for prompt effect on old apple or pear trees?

8. Make a list of all the plants that you can find producing aërial roots, and try to explain their use in each case.

9. What common plants are almost always propagated by roots? What ones are propagated sometimes in this way and sometimes in other ways?

10. When roots are uncovered by the washing away of the soil, do they develop bark like that of the stem?

CHAPTER IV

MANUFACTURE, TRANSPORTATION, AND USE OF FOODS IN PLANTS

32. The problem of securing food. Plants, like animals, cannot continue to live and grow without nourishment, but like animals, they may secure the needed nourishment in a variety of ways. Reference has already been made to some of the ways in which roots, stems, and leaves are related to the plant's food supply, but we shall need to consider further the machinery and processes by means of which green plants manufacture the things that nourish them.

33. Structure of a leaf; epidermis. In Chapter II the general form of the leaf and some of its functions were discussed. A more detailed study of leaf structure and function is necessary for the discussions of the present chapter.

Most leaves consist of the petiole, or leafstalk, and the blade, or expanded portion. In some leaves there is no petiole; that is, the leaf is *sessile*, or rests directly upon the stem or branch that bears it. In some leaves the blade is divided into several parts, or leaflets. An undivided leaf is *simple*, and a divided leaf is *compound*. Leaves vary in size, from those that are so small that they are not readily visible, to those so large that they are several feet in width or several yards in length. In color most leaves are green, but they differ in strength of color, and a careful observation usually discloses a difference in greenness between the two leaf surfaces, or between different parts of the same surface. It is possible to observe within most leaves the more or less regularly arranged veins, or fibrovascular bundles, which are not green. Also on one or both leaf surfaces, as in the mullein, begonia, and thistle, there often develop outgrowths known as hairs.

From the upper and the lower surfaces of leaves such as those of live-forever, Wandering Jew, Easter lily, corn, and spiderwort one may peel a thin, almost colorless layer which is known as the epidermis (fig. 25). The epidermis is composed of cells more or less compactly arranged. Different plants show much variation in the way in which these epidermal cells fit together.

One or both epidermal layers may include special structures known as *stomata* (singular, *stoma*) (fig. 25). Usually, when viewed from the surface, the stoma is readily seen to consist of two crescentic or kidney-shaped cells with their concave sides facing one another, so as to leave an opening between the two cells. The opening is really the mouth of a larger space extending within the leaf. It is known as the *stomatal opening*, and the two cells that are about the mouth are known as the *guard cells*. Unlike other epidermal cells the guard cells are green. The stomatal opening serves as a place of entrance for the carbon dioxide used by the plant, though carbon dioxide may doubtless enter the plant with the water from the soil. The guard cells may also press closely together or may separate until a wide circular opening is formed, and in thus closing and opening they influence the interchange of air between the interior and the exterior of the leaf. Obviously this opening and closing also affects the interchange of such gases as carbon dioxide and oxygen, as well as the outgo of moisture from the leaf.

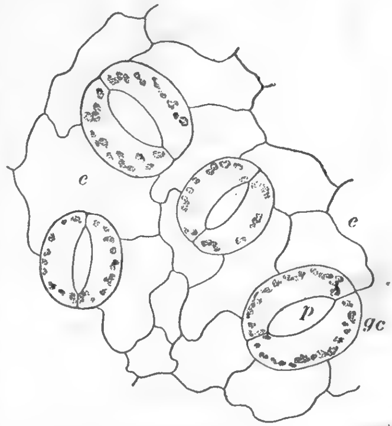

Fig. 25. A surface view of leaf epidermis from the geranium (*Pelargonium*)

Among the ordinary epidermal cells (*c*) are four stomata, each with two guard cells (*gc*) and the mouth of an air cavity (*p*). Considerably magnified

34. Internal structure of the leaf. An idea of the inner structure is best obtained by examining a cross section of a simple leaf. In general, three kinds of cells appear within the epidermis, and these are variously arranged in different kinds of plants. In simple leaves, such as that shown in figure 26, almost all the cells contain the green coloring matter, *chlorophyll* (meaning "leaf green"). These chlorophyll-bearing cells are long and are arranged side by side (*palisade* tissue) or are

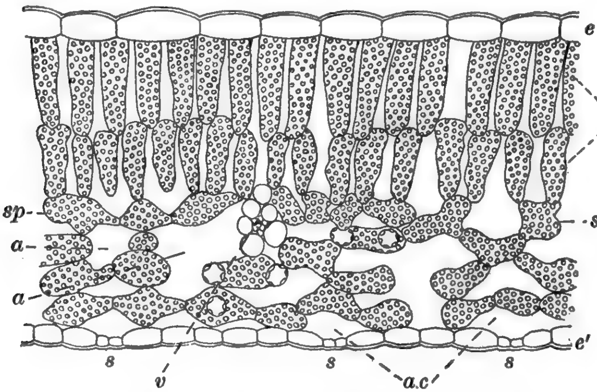

FIG. 26. Cross section of a geranium leaf

a, air space; *a.c*, air chamber; *e*, upper epidermis; *e'*, lower epidermis; *p*, palisade cells; *s*, stoma; *sp*, spongy parenchyma (usually spongy parenchyma has fewer chloroplasts than the palisade tissue); *v*, vein. Magnified 150 times. After drawing by Mrs. F. E. Clements

more irregular in form and loosely arranged (*spongy* tissue). Air spaces are abundant between these cells, but they are larger and more abundant in the spongy tissue than in the palisade tissue. When a single layer of palisade tissue and one of spongy tissue are present, the palisade tissue lies next to the upper surface of the leaf and the spongy tissue next to the lower surface; but frequently there is a lower layer of palisade tissue, not so well developed as the upper one. In cross sections of leaves the veins appear as masses of small, thick-walled cells closely crowded together and usually lying about midway between the upper and lower surfaces of the leaf.

35. Chlorophyll in the leaf. The so-called green cells of the leaf are not evenly green throughout, but contain special bodies (*plasts*, or *plastids*) in which the chlorophyll is held. These chlorophyll-bearing bodies, or *chloroplasts*, are often so numerous in the cells of the leaf as to make the cell appear to be almost of a solid green color, and when the surface of the leaf is observed, its appearance seems evenly green throughout.

It must be clearly understood that chlorophyll and the chloroplast are not the same. Plastids (plasts) may or may not contain chlorophyll, just as a sponge may or may not contain water. A plastid can properly be called a chloroplast only when it contains chlorophyll. When green leaves have stood in alcohol for a few hours, the chlorophyll is dissolved by the alcohol, the leaf is decolored, and the color of chlorophyll may readily be observed in the alcohol.

In summing up the structures of the leaf we may say that it usually consists of petiole and blade. The outer portions of the blade, both above and below, are the epidermis; in addition to the ordinary epidermal cells the epidermis contains special structures, the stomata, each of which ordinarily consists of two guard cells and a stomatal cavity; within the epidermis are the veins and the masses of green tissue — the palisade and spongy tissues; within the cells of the green tissues, in addition to other cell contents, are many plastids. These may contain chlorophyll; they are then known as chloroplasts.

36. Material for chlorophyll work. In the discussion of stomata it was stated that carbon dioxide may pass into the interior of the leaf. It was previously found that water is taken into the plant and carried through the stem. In the soil are many substances which are dissolved by the water, just as common salt or sugar would be. From this source there may pass into the plant compounds containing such things as nitrogen, potassium, phosphorus, sulphur, and iron. Carbon dioxide, which is secured through the surface of the leaf, is a gaseous substance which exists in the atmosphere,

ordinarily in the ratio of about 3 parts in 10,000 parts of air. Inside the leaf, therefore, is a supply of the so-called raw materials for food — water, carbon dioxide, and substances that were in solution in soil water.

37. The manufacture of food. Carbon dioxide and water must undergo changes before they can be used in nourishing and building up the plant. The sun shines upon the leaf and the chlorophyll absorbs some of the energy from the sun's rays. In some way, as yet unknown, this energy serves to break up the compounds water and carbon dioxide into the carbon, hydrogen, and oxygen of which they are made. The carbon, hydrogen, and some of the oxygen immediately unite again — not, however, into the compounds carbon dioxide and water, but into new compounds. These rapidly pass through several changes and may finally become sugar and starch. At present the changes that take place before starch and sugar are formed are not all known, but enough is known of them to show that they are quite intricate. Some of the oxygen resulting from the breaking up of water and carbon dioxide is set free and may pass out into the air. The oxygen thus set free by plants may be collected as shown in figure 27, and then tested.[1] This process that is carried on by green plants is a principal factor in maintaining the oxygen supply that is so necessary to the life of animals. Plants also use free oxygen in some of their later food-making processes. This series of occurrences, by means of which green plants under the influence of sunlight make foods such as starch and sugar from carbon dioxide and water, is known as *photosynthesis*. The word *photosynthesis* means "putting together by means of light." [2]

Sugar and starch (carbohydrates) may be used in the nutrition of the living parts of the plant; or, by the addition of

[1] If a test for oxygen is made, it is best to precede the ordinary test by an experiment with oxygen that has been prepared by the electrolysis of water. Test the oxygen so prepared with a lighted splinter, as more meaning will then attach to the test of oxygen set free by the plant.

[2] See Appendix, page 343.

some of the compounds of nitrogen, potassium, phosphorus, or other substances, these things may be made into more complex foods known as proteins. Many stages of the process of making these more complex foods are not known, and these are too intricate for extended discussion at this time. The leaf or other parts of the plant may be used as the place where proteins are made. They may be made immediately after the carbohydrates, or later, but sooner or later some protein food is as necessary to the continued life of plants as of animals.

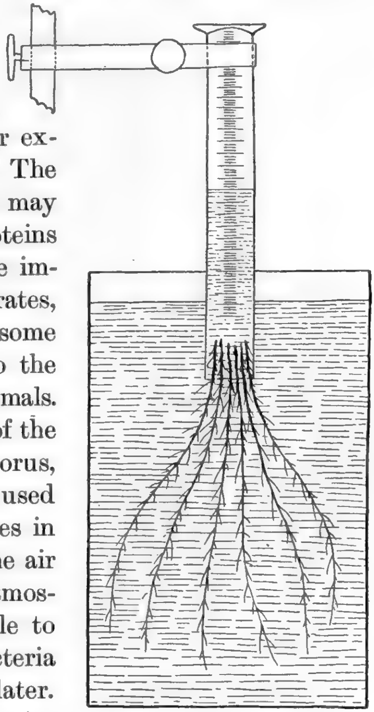

FIG. 27. Apparatus for collecting oxygen from working plants

Water plants are submerged with one end in the mouth of the graduate. Bubbles of oxygen pass upward from the cut ends of the stems and crowd out some water from the previously filled graduate. The ordinary test for oxygen—with a burning stick—will determine whether it is present. In such an experiment care must be taken to see that there is plenty of space about the collecting tube, to permit free passage of the gases that are in the water. After Ganong

The soil is the usual source of the nitrogen, potassium, phosphorus, and other substances that are used in addition to the carbohydrates in making proteins. Although the air is 78 per cent nitrogen, this atmospheric nitrogen is not available to plants, except to certain bacteria which are to be discussed later. From the soil, compounds containing nitrogen and other substances may be dissolved in water and then carried into the plants. Fertile soils are those which contain in available form large quantities of the things which plants use for food-making. Replenishment and growth of new parts can take place only by means of foods, and since the plant makes its own supply, the importance of the process is very great.

Often green plants make more food than they use at the time, and this surplus food may be stored or reserved in some way. Stored food may or may not be used later by the plant, and may oftentimes become the food of other plants, of animals, or of men.

38. Food transported by the plant. In all except the simplest plants the reserve food is carried from the cells in which it was manufactured, into other cells. In plants with fleshy leaves, like the houseleek, the century plant, the common purslane, and many others, the greater part of the stored starch and other nutritive materials has only been carried to the leaf interior from the outer portions of the leaf, where photosynthesis and other manufacturing processes go on. The distance traversed may be only a small fraction of an inch, but in case much of the food is stored in underground parts of the plant, it may have been carried for long distances — in large trees, sometimes more than a hundred feet before it reaches the root at all.

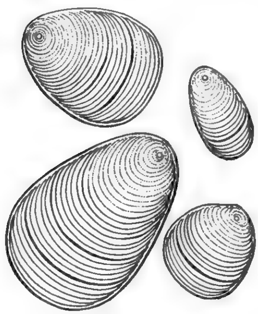

FIG. 28. Starch from rootstock of canna

Magnified 300 diameters

39. Form in which food is transported. As already stated, one of the products of photosynthesis in most plants is starch. This is deposited in or about the chloroplasts, during their exposure to daylight, in very minute grains. In the course of the night these disappear, so that testing a leaf with iodine[1] shortly before daylight usually gives no result. A leaf cut off from the stem before nightfall, however, responds readily to the iodine test for starch in the morning. This, of course, shows that the starch made during the day remained in the leaf cells, where it was formed. It is very generally true that starch carried from any part of the plant to another part is first changed to sugar and travels in the form

[1] This turns starch grains blue or almost black.

of a weak solution of sugar in water. On its arrival at the storage region (for example, the tuber of the potato plant) the dissolved sugar is reconverted into starch by the action of minute, colorless corpuscles of protoplasm, known as *leucoplasts*. The starch grains deposited for storage (fig. 28) are many times larger and show a far more definite structure than those formed in the chloroplasts during photosynthesis.

40. Diffusion and osmosis. It is clear that plant food must pass from within certain cells into others, and the way in which this occurs may be made clearer by the use of simple illustrations. If some dried raisins or prunes are placed in pure water it will soon be noted that the outside membranes, which at first were contracted and wrinkled, have become distended. Water has passed through the fruit coating and is retained within it. After a longer time it will be found that the water outside the fruit has become sweet, owing to the outward passage of dissolved sugar from within the fruit. If a little molasses is poured into a straight-sided jar, and a disk of porous paper is placed so as to cover the molasses (to prevent instantaneous mixing), and water is then carefully poured upon the disk of paper, the water will for a considerable time appear clear and colorless. Only after some hours will the molasses rise and mingle much with the water, or the latter perceptibly thin the molasses. This process, by which two liquids in contact become mixed by the interchange of inconceivably minute portions (molecules) of both liquids, is called *diffusion*. The tendency is for the two liquids to become completely intermingled, so that at last all portions of the mixture are of precisely the same composition. Similarly, if a dense liquid surrounds a plant cell, water passes more rapidly outward than inward, and the remaining internal parts of the cell collapse, or *plasmolyze* (fig. 29), because of the loss of water. This merely illustrates the fact that interchange of liquids may take place in either direction through a membrane, but is more rapid from the less dense to the more dense liquid. The mingling of liquids that are separated by a partition which one or both of them

can penetrate has received the special name of *osmosis*. Osmosis is not quite so simple as diffusion, since the movement of particles of the liquids is a good deal affected by the nature of the partition. In Chapter II it was stated that soil water may be taken up by root hairs. It may now be seen how osmotic action affects this process of taking up water by root hairs. By osmosis soil water may pass through the root-hair walls into the interior of the root hair and thence to other root cells. Obviously, when the liquids of the soil are more dense than the liquids within the root hairs, the root hairs will lose some of their water to the soil outside, and if enough water is lost in this way, the contents of the root hair may become plasmolyzed.

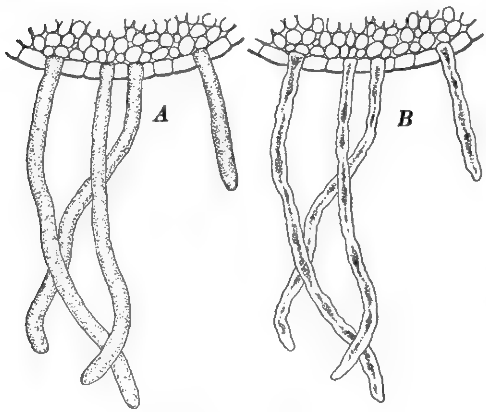

FIG 29. Root hairs

A, in normal condition; *B*, the same root hairs after being treated with a solution of common salt

41. How food is carried through plants. Applying the principles of osmotic action to the case of a starch-loaded leaf, it is evident that, as fast as the starch grains temporarily deposited in the chloroplasts of the leaf are changed into sugar, some of the sugar in the denser cell sap thus produced will pass on to the more watery sap of adjacent cells. From these cells, in turn, portions of sugar will pass on to still more distant cells. In a similar way, when a potato tuber is planted and begins to sprout, the sugar formed from the reserve starch in the potato passes into the more watery sap contained in the sprouts. This sap is constantly losing sugar that is used as building material for the young growing stems and leaves,

and the supply of materials for growth is maintained by the addition of new portions of sugar coming from the tuber.[1]

42. Channels through which food is transported. Many kinds of living tissue serve as channels for the conveyance of food from one part of the plant body to another. The main route for the transportation of food in flowering plants is through special tubular cells which form the *sieve tubes*, so called from the perforated plates found at the ends or along the sides of the nearly cylindrical cells of which the tubes are built up. In dicotyledons these sieve tubes occupy a region of the stem immediately outside of the cambium, as shown at *o* in figure 42, *A* and at *si* in figure 43. The fact that most of the plant food prepared in the leaves is carried down through the sieve layer of the bark is well shown by the behavior of a willow cutting from which a ring of bark has been removed. If the cutting is stood with its lower end in water but with the girdled part out of water, enough constructive material will pass down through the sieve layer to send out roots from the upper edge of the ring, but few or none will appear at its lower edge. In the meantime water is freely carried upward through the sapwood. In early times the process of clearing woodlands for farming purposes was made less laborious by girdling the trees, which soon died and at length fell and were burned. Would the girdling process be more effective if a good deal of the sapwood, as well as the bark, were removed from the ring? In woody dicotyledonous stems there are radiating lines of cells (medullary rays) running outward from the center toward the circumference of the stem. Food is stored in these rays, and they are also lines of conduction of foods.

43. Food storage. In the trunks of trees stored food may be present in various forms, as starch, sugar, oil, and proteins. In the autumn many kinds of sapwood turn deep blue or black

[1] It is not possible here to go into details concerning the transportation of other kinds of plant food than starch and the sugars. That of proteins is especially difficult to trace.

if tested with iodine for starch. During the winter much of this starch is often converted into sugar or oil. The presence of proteins in wood is so general that the cheaper grades of white paper, largely made of wood pulp, at once turn yellow on being moistened with nitric acid (the protein test). When thus tested, paper made wholly of cotton or of linen rags shows little change. The plant food stored in wood is most abundant in the younger portions (sapwood) and above all in the cambium layer.

Underground stems and roots (fig. 30) often contain large quantities of stored food and are thus useful in tiding the plant over that period of the year when no food can be made. In the same way they are of service in storing water, as has already been shown (sect. 21). There are many shade plants, such as trilliums, dogtooth violets, wild ginger, May apple, and others, which leaf and flower early in the spring and do a large part of the storing of food for the next season in their rootstocks, tubers, or bulbs, before the trees under which they grow are in such full leaf as to shut out the abundant light necessary for photosynthesis.

Fleshy leaves often contain much stored food, as in the familiar century plant, which, after storing food for fifteen years or more, may use this food in producing an immense flowering stalk and many flowers and seeds. By the end of the flowering season the leaves, in the case of century plants that were tested, had lost more than 90 per cent of their weight. This flowering stalk may reach a height of over 33 feet and a weight of some 500 pounds. Its average growth in height during the month of most rapid elongation has been found to be about $5\frac{1}{2}$ inches a day. Not only the plant food but also nearly all the water for this rapid growth is furnished by the leaves.

44. Relation of food and water storage to duration of life. It is usual to divide plants, according to their duration of life, into three classes: *annuals*, those living one year or less; *biennials*, those living two years; *perennials*, those living more than two years. The boundaries between these classes are not always definite. For example, winter wheat is an annual,

though it does not seed until the next summer after it is planted; and the cotton plant, the lima bean, the tomato, and the castor bean are instances of plants which with us are cultivated as annuals, but which in warm climates live several years, the castor bean growing into a large, almost tree-like shrub. Plants which live for more than one year usually have food stored in their roots.

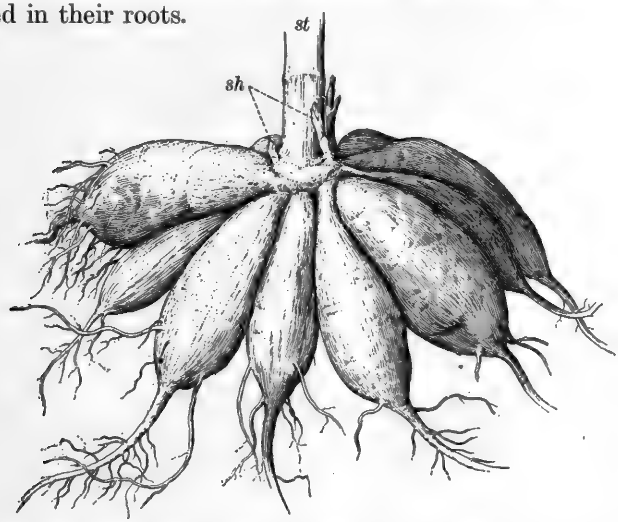

FIG. 30. Clustered, fleshy roots of the dahlia, with much stored plant food, in early spring

st, remains of last year's stem; *sh*, young shoots beginning to sprout from upper ends of roots. One fourth natural size

Such biennials as beets, carrots, and parsnips store up much food in the root[1] during the first summer's growth, and form a large tuft, or rosette, of leaves, but do not develop much stem aboveground. During the second summer the stored food is consumed in the production of leafy stems bearing flowers and fruit, and in the autumn the root appears quite withered and nearly dry.

Herbaceous perennials, like the dahlia (fig. 30) and the common rhubarb, store food in the root during the summer

[1] The underground part of the carrot and the parsnip is part stem and part root.

and consume part or all of it in the growth of the following spring. Trees and shrubs in temperate or cold climates store starch and other foods in the roots, as well as in the stem. It is the stored food in the root that enables such plants as rhubarb, the peony, some buttercups, sweet cicely, the dandelion, and many others to make a quick growth in the spring, before the weather is warm enough for the manufacture of much plant food. The starch, sugar, and proteins which abound in many roots or root-like portions of plants make them valuable for food, as in the case of beets, turnips, carrots, parsnips, sweet potatoes, salsify, and the cassava plant, from which tapioca is made.

45. Digestion and assimilation. Plants as well as animals must make solid foods into solutions before these foods can become parts of the living protoplasm. The processes which make these solids into solutions are known by the general name of *digestion.* Digestive processes vary widely in different living things. Animals usually have special organs for this work, but plants do not have them. The process is essentially the same in both, however, though it may be much more complex in some higher animals than in plants. Plants form certain chemical substances known as *enzymes* (see sect. 157), which operate in ways that are little understood, but which result in digesting foods.

By a process known as *assimilation* digested foods may be taken into living protoplasm and made a part of it. What occurs in assimilation no one really knows. Digested food becomes living protoplasm, and in so doing it becomes more complex in structure. Thus far it has been impossible for scientists to follow the process closely enough to determine the changes which assimilation makes, though it is known that living substance is the outcome.

46. Respiration. Food that has been digested and assimilated, thus becoming living tissue, is later changed by the process known as *respiration.* It is common to associate respiration, in both plants and animals, with the interchange of

gases between the exterior and the interior of the living body — between the lungs and the air in the case of the higher animals and between the leaves and the air in the case of the higher plants. This interchange is, however, no longer regarded as the fundamental thing in respiration, since respiration takes place in active, living protoplasm in all parts of the plant. It consists of decomposition of protoplasm or of some of its parts, or (as is supposed by some botanists) it may consist of decomposition of food materials that have not yet become assimilated so as to become protoplasm. Through respiration complex plant substances are broken down, and the energy released by this decomposition is the energy by means of which plants carry on their work. Energy in the form of heat is also one of the results of respiration. Respiration may occur in the absence of free oxygen, but it is more complete, and thus releases more energy, when oxygen is present. When respiration is complete, it results in the formation of various compounds, of which carbon dioxide and water are conspicuous. Carbon dioxide and water may be carried away from the plant through the leaf or other parts, and the oxygen supply may enter in the same way. It is evident, however, that the transfer of these gases is merely an incident associated with the real respiration, which consists in the decomposition of complex substances and the release of energy therefrom. It is also evident that, so far as respiration is concerned, plants and animals behave in the same way. It should be noted that in photosynthesis green plants utilize carbon dioxide, though they, like other plants and animals, may produce carbon dioxide as one of the products of respiration.

47. Importance of the food cycle in plants. The importance of the food cycle of green plants can scarcely be overestimated. The human race depends, directly or indirectly, upon photosynthesis and the storage of food by plants. Men have selected and improved those plants which produce the most desirable food in the largest quantities. They have studied, and must continue to study, the conditions of soil and the climatic

conditions under which plants produce most abundantly. They must study and improve those plants which are found to perform their nutritive functions in such a way that large amounts of desirable food are produced economically.

The island of Chung-ming, at the mouth of the Yangtze River in China, has an area of 270 square miles. It has but one large city, yet the whole island has a dense population. The inhabitants have made such a study of the productivity of plants that the island is said to support a population of 3700 people per square mile. Our own rural population of 61 per square mile of improved land suggests by comparison the necessity of further study of the food cycle of plants and of the conditions under which our economic plants thrive best.

48. Independent and dependent plants. So far in this chapter we have spoken only of plants that have chlorophyll and can make their own food from materials that are not ordinarily regarded as nutrient substances; that is, we have discussed only *independent* plants. But there are many plants that do not possess chlorophyll, and even some that do possess it, that are *dependent* for their food upon the chlorophyll work of plants similar to those we have already discussed. Then some plants are dependent, not for food, but in other ways. Some dependent flowering plants, like the woodbine, or Virginia creeper, are almost independent. A woodbine may grow in the open and attain its full size, but in dense woodlands grapevines, woodbines, and many other climbers can only make a normal growth by climbing upon the trunks of trees and so raising themselves into the light.

49. The food supply and dependency in flowering plants.[1] The principal groups into which dependent flowering plants are divided are as follows:

1. Lianas, or climbers.
2. Epiphytes, or plants which rest upon other plants.
3. Saprophytes, or plants which live on the products of the decay of organic matter.

[1] Dependency among lower plants is discussed at length in later chapters.

FIG. 31. Spanish moss, an epiphytic flowering plant

These plants often grow in large numbers upon the branches of trees in the southern part of the United States. Photograph by B. Mackensen

4. Parasites, or plants which live upon other living plants or animals (known as host plants or animals).

5. Carnivorous plants, or those which capture small animals, such as insects, and live wholly or partly upon them.

Lianas, which were mentioned in the preceding section, get their living without receiving from other plants any benefit except that of position. The other groups (2–5) are discussed in the following sections.

50. Epiphytes. Unfortunately for students in temperate climates, flowering epiphytes are mainly confined to the tropics. The Spanish moss (fig. 31) is one of the few exceptions. A visit to any large greenhouse in which orchids are kept will, however, suffice to give a fair idea of the appearance of some

FIG. 32. Indian pipe (*Monotropa uniflora*), a symbiotic saprophyte

The plants are white from lack of chlorophyll

of the most characteristic plants which live upon the trunks or branches of trees. Since these plants usually have little or no permanent water supply about their roots, they must be provided with means of absorbing water rapidly during rains, and of retaining it between one rainfall and the next. The Spanish moss, which is rootless, takes up water along the surface of the stems by the aid of special absorbent hairs which grow from the epidermis. This plant can become almost dried up without permanent injury. Other epiphytes, as orchids, have specialized water-absorbing tissues upon root, stem, or leaf surfaces, and from these tissues water escapes slowly in dry weather.

51. Saprophytes. In general, the seed plants which are saprophytes occur only in the forest or under shrubs. It is in such situations that plants find a most abundant supply of *humus*, or decaying organic matter. *Complete saprophytes* — that is, those which

FIG. 33. A single Indian pipe plant (*Monotropa uniflora*)

Note the slender stem and reduced leaves

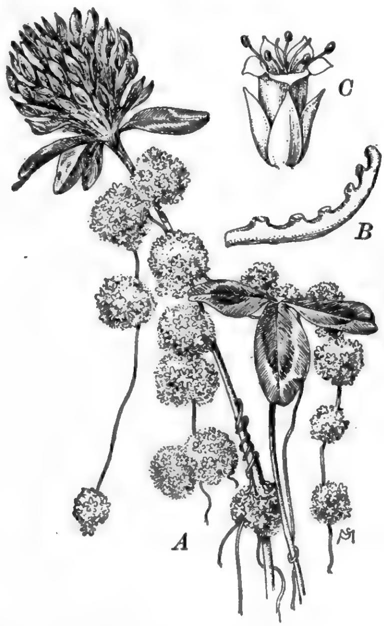

FIG. 34. Clover dodder, parasitic on red clover

A, habit sketch of part of the parasite and the host; *B*, portion of stem of the dodder, showing protuberances from which haustoria pass into the stem of the host; *C*, a single flower of the dodder. *B* and *C* considerably magnified. Modified after "Flora Danica"

cannot exist without an abundant supply of soluble organic matter in the soil or sub-stratum — are always pale, or even white, from partial or complete absence of chlorophyll (fig. 32). Their leaves are small and scale-like (fig. 33). Their roots are usually short and have little tendency to branch. Some

saprophytes have fungi growing upon their roots in such ways as to assist in securing food. These are called *symbiotic saprophytes.* The Indian pipe (*Monotropa*) often has these root fungi (mycorrhiza).

Partial saprophytes, among flowering plants, are not easily recognized by their form and color, but may be known by their inability to flourish without considerable humus in the soil.

52. Parasites. The dodders are the most familiar flowering parasites. One of the commonest species is abundant in the central and northeastern states, its threadlike, golden-yellow stems forming great tangled masses on many kinds of plants, as clover, goldenrods, and willows, that grow in damp places. The dodders (fig. 34) and some root parasites, such as the beechdrops, squawroot, and cancer-root, are *complete parasites* and have no green foliage. Other plants, such as the mistletoe (fig. 35), have green leaves and do photosynthetic work, but depend on the host for water and the mineral substances dissolved in it. Such plants are called *partial parasites.*

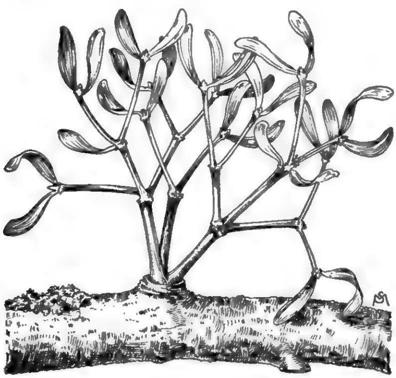

FIG. 35. Mistletoe growing upon a branch of an apple tree
After Bonnier and Sablon

53. Damage inflicted by parasites. Many parasites take so much water and plant food from the host that they may cause serious injury to cultivated plants and to forest trees. The flax dodder and the clover dodder often do great damage to crops in this country and in Europe, and another species[1] is sometimes troublesome in fields of alfalfa. In the southwestern states the American mistletoe is so injurious to dicotyledonous trees that it is often necessary to cut it away from

[1] *Cuscuta arvensis.*

the trees to enable them to thrive. The European mistletoe causes much damage to apple trees in northern France and in the Tirol.

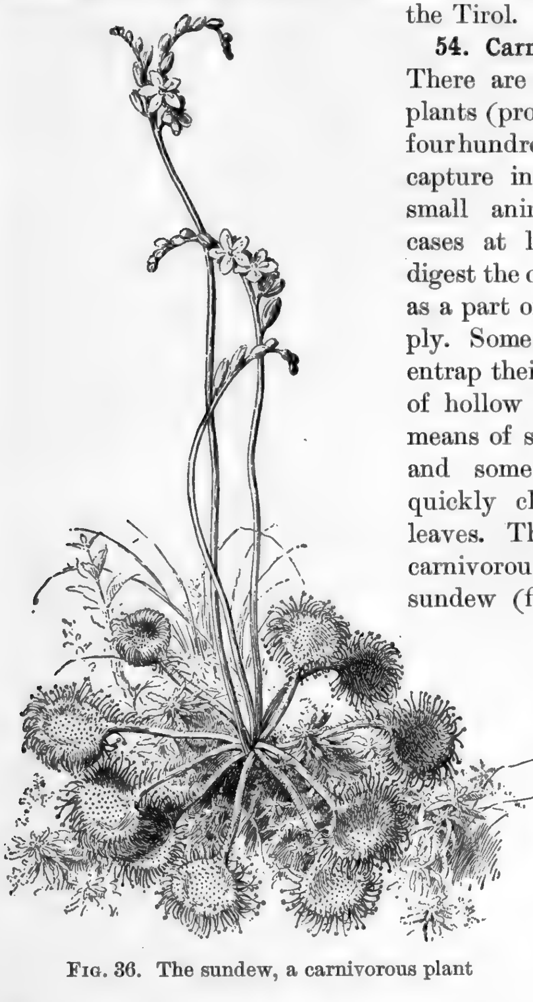

FIG. 36. The sundew, a carnivorous plant

54. Carnivorous plants. There are many kinds of plants (probably more than four hundred species) which capture insects and other small animals. In some cases at least they may digest the captured animals as a part of their food supply. Some of these plants entrap their prey by means of hollow leaves, some by means of sticky secretions, and some by means of quickly closing, trap-like leaves. The best type of carnivorous plant is the sundew (fig. 36). This is a low marsh plant having hairy leaves and a slender flower stalk, on which are borne small white flowers. In one widely distributed species the leaf consists of a narrow blade tapering into a moderately long leafstalk. On the inner surface and around the margin of the blade are borne a number of short bristles, each terminating in a knob

which is covered with a clear, sticky fluid. When a small insect touches one of the sticky knobs, it may be held fast, and in that case the hairs at once begin to close over it. The insect soon dies and usually remains for many days, while the leaf pours out a juice by which the soluble parts of the insect are digested. The liquid containing the digested portions is absorbed by the leaf and contributes an important part of the nourishment of the plant, while the undigested fragments, such as legs and wing cases, remain on the surface of the leaf or may drop off after the hairs let go their hold on the captive insect. The pitcher plants have cylindrical, liquid-containing leaves, with inner hairs so arranged that insects get into the leaves very easily and get out with great difficulty, if at all. The leaves of the Venus's-flytrap close so quickly that they sometimes catch insects which may come in contact with them.

PROBLEMS

1. Which are greener, leaves which are densely shaded or those which are exposed to the sun? What makes the difference?

2. Will alcohol dissolve the chlorophyll more quickly from densely shaded or from openly exposed leaves? Why?

3. Under what conditions could a field of corn lose water to the soil instead of securing water from the soil?

4. What would be the effect upon animal life if green plants should manufacture no more food than they consume in their own growth?

5. Leaves often give a strong starch reaction in the late afternoon and none in the early morning. Can you account for this?

6. It was found by some students that a corn plant elongates about four times as much between 6 P.M. and 6 A.M. as between 6 A.M. and 6 P.M. Can you account for this fact?

7. Fields of grain are often more or less wilted at noon on hot summer days and regain their turgor at night even when no rain has fallen. Can you account for this fact?

8. In trying to kill plants in the lawn or trees in the cultivated fields people sometimes put salt upon the roots or stumps. What is the botanical explanation of this practice?

9. Can you arrange an apparatus to test the pressure with which maple sap flows from a cut branch?

10. Can you explain the fact that you cannot get seed from beets and carrots the same year that the plants are grown from the seed?

11. It is often stated that one difference between plants and animals is that plants use carbon dioxide and throw off oxygen, and animals use oxygen and throw off carbon dioxide. In what ways is this statement correct and in what ways is it an error?

12. In what sense is it true that the sun is the source of the energy by means of which plants and animals do their work?

13. In what ways is it important to your community that the people should know something about photosynthesis?

CHAPTER V

THE STEM AND THE LEAF

FIG. 37. Beefwood, *Casuarina*, an Australian switch plant destitute of foliage leaves and depending on the chlorophyll-containing cells of the bark for photosynthesis

Photograph by Robert Cameron

55. Work of the leafy shoot. How plant food is made from raw materials has been briefly explained in Chapter IV. In almost all of the higher plants this food-making is carried on by the coöperation of the stem and the leaf. Taken together, they are known as the *shoot*, so that the parts of a flowering plant (before it begins to flower) are root and shoot.

56. Photosynthesis in the stem. Among seed plants in general it is the leaves that do by far the greater part of the work of photosynthesis, but some plants, as the cacti (fig. 66), are practically leafless [1]

[1] That is, they have no leaves which can do any food-making or which at all resemble ordinary leaves.

JULIUS SACHS

Julius Sachs, a noted German botanist (b. Breslau, 1832; d. Würzburg, 1897), was a most careful observer of the ways in which plants live and work. He had a remarkably clear and forceful style of writing and an unusual ability in making illustrations. As investigator, writer, and teacher he organized the somewhat disconnected discoveries of others and, adding his own discoveries, established the science of plant physiology. His textbooks were unsurpassed in influence and gave to many students their first general view of botany. He published many important contributions to our knowledge of germination, the work of chlorophyll, and other processes of food-making and food transportation

all the year round, and in these photosynthesis is carried on by the green layer of the cortex beneath the epidermis of the stem.

In many dry countries there are switch plants, which either bear a few little leaves during a small part of the year or are entirely leafless, as is shown in figure 37. Like the cacti, such plants, and others with flattened stems and little leaf surface (fig. 38), do the greater part or all of their photosynthetic food-making in the green cells of the cortex of the stem.

Many of our common forest trees and shrubs do food-making in the green layer of the bark of the young twigs, until this is shut away from the light by layers

Fig. 38. Branches of *Muehlenbeckia*, a plant with scanty leaf surface and flattened stems which do most of the photosynthetic work of the plant

f, flowers; *l*, leaves; *s*, stems. One half natural size

of cork which form outside the green bark. Photosynthetic work is also done by the stems of most common annual plants of the farm and garden, such as corn, beans, peas, and potatoes.

FIG. 39. Twigs of coffee tree, showing how leaves are supported so as to give them complete exposure to light

57. The stem raises leaves into the light. Competition for light is extremely common among plants. One of the main reasons why the surface of the earth in a very dense forest — the *forest floor*, as it is called — is comparatively bare of flowering plants is that they cannot get enough light there to live. In a cornfield it often seems as if the weeds were

going to outstrip the corn, but if they are kept down until the corn has begun to shade the ground well, there will be little further trouble from most weeds. If, however, the corn is cut early for green fodder or for ensilage, a rank crop of weeds will spring up between the rows. So foxtail and other weeds begin to flourish among the stubble as soon as oats, wheat, or rye have been reaped.

The stem, then, by lifting the leaves up into the sunlight and supporting them there in favorable positions (fig. 39), gives them a chance to do photosynthetic work, so that the whole plant prospers. Even climbing plants like the English ivy (fig. 40), with stems that bend away from the light toward a supporting rock or tree trunk, turn their leaves to face the light. There are many plants — creeping kinds, like white clover, and those with flattish clusters of leaves, like the dandelion — which flourish in places

Fig. 40. An English ivy (*Hedera*) grown in front of a south window

WW, the line of the window casing; all to the left of this is unlighted wall. The tips of the shoots (*t*) avoid the light; the young leaves (*l*) have assumed no definite position; the mature leaves are nearly at right angles to the light coming from the direction of the arrow

where they can cover the surface of the ground closely enough to prevent too severe competition from plants that might shade them.

As a result of this competition for light, plant stems often become greatly lengthened. Any one who is observant and familiar with things out of doors must have noticed the difference in form (*habit* it is called by botanists) of such plants as giant ragweed (*Ambrosia trifida*) and hemp; they grow tall and little branched when in dense clumps, but low and spreading when they stand alone. Full-grown trees, such as pines, are nearly branchless for most of their height when growing in dense forests, but are low and broad-topped, with many lateral branches, when growing alone in a pasture.

58. Plants blown down by wind. Most farmers who grow any kind of grain have had losses from lodged grain — that is, from crops which have been more or less completely blown down by a windstorm, and especially by a wind accompanied by a heavy rain. Forest trees are often blown down by severe winds (fig. 41). Where they pass through forest tracts, the violent rotary storms commonly known as cyclones frequently leave behind them windfalls, in which the tree trunks lie in piles for long distances. Individual plants of any kind of grain, and tall, slender forest trees growing under usual conditions, are greatly protected by their neighbors. The whole mass of plants, standing as close together as they do, intercepts much of the wind, so that the single plant is exposed to only a small fraction of its total force.

59. Growth in length of stem. Under favorable conditions the younger regions of the stem continue for some time to increase in length. The rate of growth varies greatly in different plants: the giant ragweed and certain kinds of sunflowers may grow to a height of 10 or 12 feet, and climbers like gourds and hops, to a length of perhaps 40 feet, in a single summer. On the other hand, pine seedlings, during their first summer, grow to be only from 1 to 3 inches high, and oak seedlings less than 5 inches. For a time the growth

per year continues to increase, and then diminishes. For example, the long-leaf pine (fig. 229) grows only about $\frac{3}{4}$ inch the first year. For the first fifty years it makes an average annual growth of 14 or 15 inches; for the next fifty years, 4 or 5 inches; and from one hundred years to extreme old age, about $1\frac{1}{2}$ inches. It usually lives about two hundred years.

FIG. 41. An isolated white oak tree destroyed by a violent windstorm

Photograph by Paul Sargent

The growth of the younger portions of most plants is quite unequal, as may be learned from the study of a rapidly growing stem, such as the morning-glory.[1] It will also prove interesting to measure such plants as corn, broom corn, hemp, and pole beans, to determine whether they elongate more by day or by night, and during warm or during cool weather.

[1] For an illustration of this unequal growth, see Bergen and Davis, Principles of Botany, p. 17. Ginn and Company, Boston.

60. Internal structure of the young dicotyledonous stem.[1] It is a difficult process, involving much careful work with the microscope, to trace the earliest steps in the development of stem structure in the seedling plant. It is therefore better, for our purpose, to begin with the study of the stem at the end of the first season's growth.

In early spring, before the buds begin to open, a twig of willow, alder, or hickory is readily stripped of its bark. When split through the middle it shows a hollow cylinder of wood inclosing the cylindrical pith. These structural constituents — bark, wood, and pith — make up almost the entire bulk of the stem.

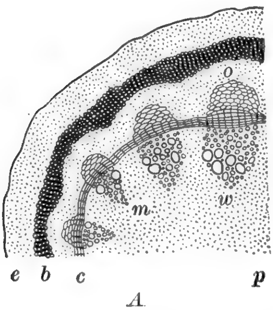

FIG. 42, *A*. Diagrammatic cross section of one quarter of a one-year-old stem of Dutchman's-pipe (*Aristolochia*)

e, region of epidermis; *b*, hard bast; *o*, outer, or bark, part of a bundle (the cellular portion under the letter); *w*, inner, or woody, part of bundle; *c*, cambium layer; *p*, region of pith; *m*, medullary ray. The space between the hard bast and the bundles is occupied by thin-walled, somewhat cubical cells of the bark. Magnified about 15 diameters

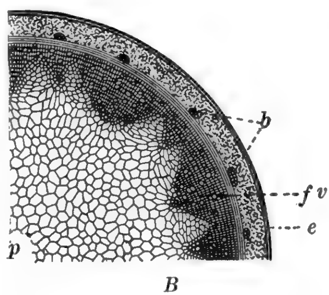

FIG. 42, *B*. Diagrammatic cross section of one quarter of a sunflower stem

p, pith; *fv*, woody, or fibrovascular, bundles; *e*, epidermis; *b*, bundles of hard-bast fibers of the bark. Somewhat magnified

Examined in section by the aid of a good lens, young dicotyledonous stems are readily seen to be classifiable into two

[1] See also sections 61–65. The stems of many gymnosperms — for example, trees of the Pine family — in their general structure much resemble the dicotyledonous stems. For a general account of the stem structure of dicotyledons and monocotyledons see Coulter, Barnes, and Cowles's "Textbook of Botany," Chap. iv, A. ANGIOSPERMS.

groups: one with *no continuous woody cylinder*, like the stem of such a climber as the Dutchman's-pipe (fig. 42, *A*), and one with *a continuous woody cylinder*, like that of the sunflower (fig. 42, *B*). The real difference between the two kinds of stem is that, like most climbers, the stem of the Dutchman's-pipe begins the season's growth with a set of separate fibrovascular bundles which remain separate, while in the sunflower the bundles are at first separate but soon join each other. The boundary between bark and wood is a layer of thin-walled cells (*c*, fig. 42, *A*), the *cambium layer*. It is this cambium, its cells filled with mucilaginous protoplasm, that makes up the slimy layer just outside the wood, from which the bark peels so readily in early spring, when boys are making whistles or stripping off sheets of slippery-elm bark. It is important to notice that each fibrovascular bundle consists of an outer portion, *o*, which belongs to the bark, and an inner portion, *w*, which belongs to the wood.

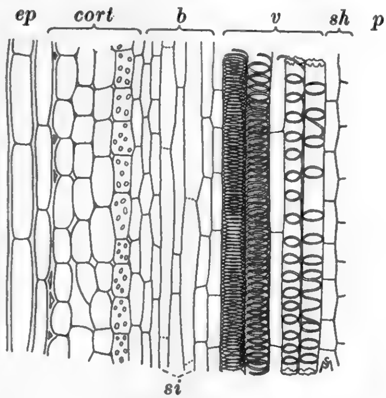

Fig. 43. Lengthwise section of a young dicotyledonous stem

ep, epidermis; *cort*, cortex; *b*, bast; *v*, vessels; *sh*, sheath surrounding pith; *p*, pith; *si*, sieve cells of the bast. Magnified about 90 diameters. After Bonnier and Sablon

A much better idea of the details of structure of the several regions of the stem can be gained from a lengthwise section, like that shown in figure 43, than from cross sections, like those of figure 42.[1] The uses of some of the parts shown in figure 43 are briefly stated on the following page.

[1] Since the type of stem structure shown in figure 43 is not exactly like that of the other two figures, it will not be possible to identify all the kinds of cells shown in figure 43 with those of the other two. Note especially that in figure 43 the cambium is not readily distinguished from the overlying tissues, and that no distinct layer of heavy-walled bast fibers is found.

1. The epidermis (*ep.*) serves as a protective covering for the young stem and, to a considerable extent, prevents it from becoming dried up.

2. The layers of cork cells soon formed just beneath the epidermis (not separately shown in the diagram) prevent loss of water and consequent drying up.

3. The layers of green cells which at first directly underlie the epidermis (not distinguishable in the diagram) are useful in the manufacture of plant food.[1]

4. The fibrous cells of the hard bast give toughness to the stem.

5. Certain thin-walled tubes (*si*) of the outer portions of the bundles carry manufactured plant food in liquid form downward, or toward the roots.

6. The cambium layer (in figure 42, *A* shown proportionally thicker than it really is) grows and forms new bark on its outer side, while on its inner side it forms new wood (see sect. 64).

7. The vessels, or ducts (*v*), of the bundles carry water upward, or toward the leaves. The fibers, which constitute a considerable portion of the wood part of the bundles, stiffen the stem and make it tougher.

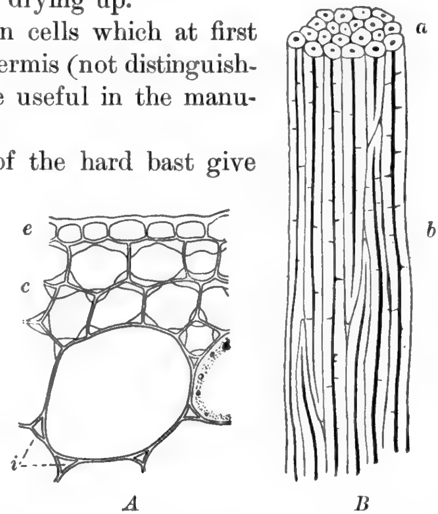

FIG. 44. *A*, strengthening and other tissue from stem of balsam (*Impatiens*); *B*, a group of hard-bast fibers

e, epidermis; *c*, collenchyma; *i*, intercellular spaces between large parenchyma cells; *a*, cut-off ends; *b*, lengthwise section of fibers. Greatly magnified. *A*, after Strasburger; *B*, after Tschirch

61. Strengthening cells. The cells which serve to stiffen or toughen the roots, stems, and leaves of plants belong to several different types. The two kinds shown in figure 44 are

[1] See section 56.

commonly found in the bark of dicotyledons and are often the main factors in strengthening young stems. *Collenchyma cells* (*A*) are like the thin-walled cells of the pith, but are reënforced at the angles, just as some packing boxes have strips of board nailed fast on the inside of the box at the junctions of the sides. *Bast fibers* (*B*) are extremely slender tubes with closed and pointed ends, much like a piece of thermometer tubing drawn to a point in a gas flame and thus closed. Collenchyma gives moderate stiffness to the parts in which it occurs and is highly elastic, so that it does not hinder the growth of the stem which it incloses. Bast fibers are flexible but very tough, and therefore enable the parts of the root, stem, or leaf in which they occur to resist being pulled apart. In many stems, particularly those which are more than a year old (fig. 45), a great part of the total strength is due to the presence of several kinds of fibers, of which the wood is largely made up.

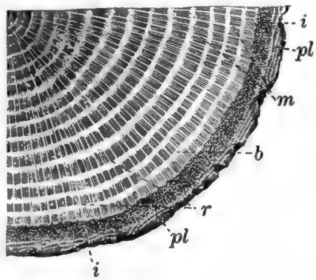

FIG. 45. One quarter of a cross section of a stick of oak wood

m, medullary rays, running from bark to pith; *r*, annual rings; *b*, boundaries between rings, porous from presence of many ducts; *i*, interior fibrous layers of dead bark; *pl*, hard plates of dead bark splitting away from each other but attached to bark beneath. Reduced

Which stem is more like a wire cable in its structure, that of Dutchman's-pipe (fig. 42, *A*) or that of the sunflower (fig. 42, *B*)?

62. Stiffness of stems. It is a familiar fact that a metal tube is stiffer than a solid rod of the same kind of metal and the same weight per foot of length. So in many plants, just as in the long bones of animals, the stems are at once stiff and light, because the material is arranged in the form of a tube, as in the bamboo, the straw of the small grains, and such flower stalks as that of the dandelion. In other cases, as in the cornstalk and in the stems of elder, the harder parts of the stem constitute a tube inside of which is much soft, light pith.

63. Limited thickening of annual stems. In stems of large dicotyledons which die to the ground every year, such as the sunflowers, ironweeds, hemp, and giant ragweed, growth in thickness goes on throughout the summer. The outer cells of the cambium continually split up by the formation of tangential partitions parallel to the bark, and so form new layers of bark. In a similar way and to a still greater extent the inner cells of the cambium form new wood, and thus the stem goes on increasing in thickness. But in such plants as those just mentioned the activity of the cambium is strictly limited; after it has given rise to a certain amount of new tissue, growth stops and the stem dies down to the ground. The death of annual stems in the autumn is often thoughtlessly supposed to be due to the arrival of winter, but it occurs just as certainly, and often after a briefer period of growth, in regions where there is no cold weather.

64. Annual thickening. In stems such as those of dicotyledonous trees and the trees of the Pine family and other cone-bearers, which live for many years, the cambium forms each year a new layer of bark and one of wood. These annual layers are usually more noticeable in the wood than in the bark, because the wood cylinders thus formed remain closely joined together (fig. 45). The newer, lighter-colored portions of the wood are known as *sapwood*, and the older portions, often darkened by the deposit of coloring matter, are known as *heartwood*. Not infrequently the heartwood decays and leaves the tree hollow.

How old is the stick of wood shown in figure 45? Did it grow at the same rate during all the years of its life? Discuss this question. Why is the name *annual rings* not an accurate one? What are they really? Is each year's growth uniform all round the stem? Had this stem any branches in the portion shown by the section? How does figure 46 suggest a method of determining the age of the stem at the time when a branch began? What seems a probable cause of the death of the branch, figure 46, *b*?

The hard-wood trees show great differences in the rate at which their trunks increase in thickness. Poplars, basswoods, willows, and red oaks, growing in good soil and unshaded, may for forty or fifty years form annual rings as much as three eighths of an inch thick, but old beeches and sugar maples in the forest, after they have passed the hundred-year limit, often grow not more than about one sixteenth of an inch per year. When very old, though still sound, they may grow only about one twenty-fifth of an inch per year.

Would it be good policy to let beeches and maples remain long in the forest after they are one hundred years old before cutting for timber? Why?

FIG. 46. Formation of knots due to branches. The figure gives part of a lengthwise section of a stick of birch wood

a, section of the base of a branch which persisted until the tree was felled; *b*, section of the base of a branch which died some years earlier and is now covered by several layers of younger wood

65. Growing points. The extreme tip of the live stem or root of a dicotyledon consists of a more or less conical or cushion-shaped mass of tissue composed of thin-walled cells like those of the cambium layer. This portion of the stem or root is called the *growing point.* Every live twig and rootlet is tipped with a growing point, and it is by the rapid sub-division and consequent multiplication of these cells that the lengthening of the main stem and its divisions, and of every root, takes place.

All branches originate from growing points, which are usually developed along leaf-bearing portions of the stem, each one just above the point where a leaf is attached. In their earliest beginnings both leaves and rudimentary branches consist wholly of thin-walled cellular tissue. Fibrovascular bundles, connected with those of the underlying stem, soon appear in the branches and leaves as their development goes on.

As the branch lengthens, its wood cuts across the annual layers of the stem from which it grows, and the branch forms its own annual rings. Knots are not all due to the growth of branches, but most of them are, as may be seen from figure 46. If a knot-forming branch dies early, new wood forms over it and covers it up, as the figure shows; but if it continues to live as long as the main stem does, it gives rise to a knot that reaches to the outermost layer of wood in the stem.

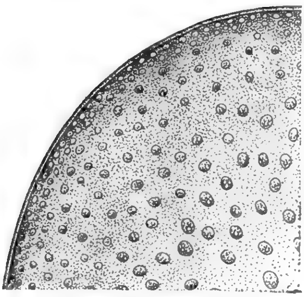

FIG. 47. One quarter of a cross section of a corn stem, showing the hard cortex and within it the soft pith, throughout which many fibrovascular bundles are irregularly scattered

In figure 46 which knot, *a* or *b*, would be the more likely to injure the timber?

66. Internal structure of the monocotyledonous stem. In the very young monocotyledonous stems of seedlings the fibrovascular bundles are constructed like those of dicotyledons. The wood elements are on the one side and the cortical elements on the other. In the full-grown stems of most monocotyledons the bundles have their vessels and other wood elements arranged in a hollow cylinder inclosing that part of the bundle which corresponds to the portion shown outside of the cambium ring in figure 42, *A*. In the adult monocotyledonous stem (when it is solid) the bundles occur scattered all through the pith, as shown in a section of asparagus or corn stem (fig. 47). No such complicated bark as that of woody dicotyledons is found in monocotyledons.

67. Growth in thickness of the monocotyledonous stem. The very young stems of monocotyledons may for a time increase considerably in diameter by the formation of new bundles within them. But in monocotyledons all the cambium becomes changed into other tissues, so that none is left, as it is in dicotyledons, to develop new tissue. In monocotyledons the bundles are said to be *closed*, while those of dicotyledons, in

which active cambium remains, are said to be *open.* The palms and similar monocotyledonous trees cannot form annual rings of wood. There are, however, a few tree-like monocotyledons in which the trunk continues for years to increase in thickness, and may reach great dimensions, but these trunks do not thicken in the same way as do the trunks of our familiar trees.

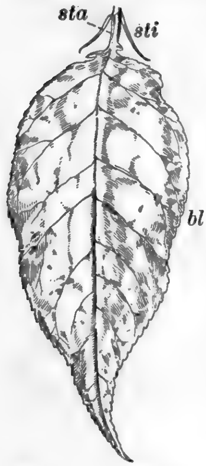

FIG. 48. A young leaf of wild black cherry

bl, blade, or expanded part; *sta*, leafstalk; *sti*, stipules, or appendages at the base of the leafstalk

Many of the woody monocotyledons are remarkable for the extraordinary length and slenderness of their stems. The rattans, for example, often climb for hundreds of feet among the tops of tropical forest trees.

68. The parts of the leaf. It already has been stated in section 11 that a leaf consists of petiole and blade. A few words may now be said about the external forms of ordinary leaves and the parts of which they consist.

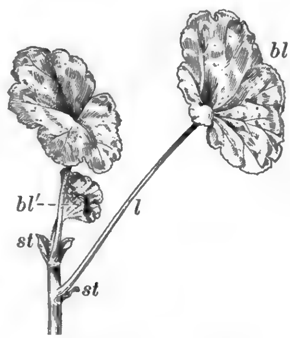

FIG. 49. Tip of a geranium (*Pelargonium*) shoot

bl, blade of a leaf; *bl′*, blade of a young leaf, only partly expanded from the naked bud; *l*, leafstalk; *st* stipules. Considerably reduced

At the base of the petiole many leaves bear a pair of appendages called *stipules* (figs. 48 and 49). In some leaves, as those of the pansy, these form an important part of the total leaf surface. Not infrequently, as in the black locust, the stipules have the form of thorns, one at each side of the base of the petiole.

In general the form of the leaf depends very much on the distribution of the groups of fibrovascular bundles known as *veins.* Most monocotyledons have

leaves with the veins running somewhat parallel to each other. Sometimes, as in the canna (fig. 50), the veins run both ways from a midrib, but oftener, as in corn and the other grasses, the veins run from the base to the tip of the leaf. This latter system of veining is most commonly found in long, narrow leaves. Most dicotyledons have net-veined leaves. These are of two types: those like the leaf of the willow, oak, and

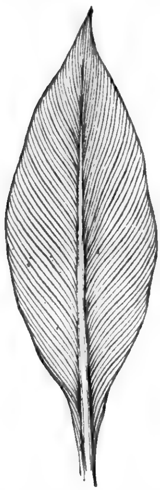

FIG. 50. Parallel-veined leaf of canna, veins running from midrib to margin

FIG. 51. An apple twig in the autumn

Alternate arrangement of leaves

peach, with the smaller veins running both ways from a midrib; and those like the geranium, hollyhock, and cucumber, with the veins radiating from the base of the leaf, like the sticks of a fan (fig. 49). Net-veined leaves with feather-like veining frequently have a length several times as great as their width, while those with fan-like veining are often roundish in their general outline. Whatever the shape of the leaf, the veining is so disposed that *a ready means of distribution throughout the leaf is offered to the water brought into it through*

the fibrovascular bundles connecting it with the stem. The importance of this is clear from what has already been said (sect. 37) about photosynthesis as a process of food-making in which the elements of water from the soil and of carbon dioxide from the air are brought together in the leaf to form sugar and starch.

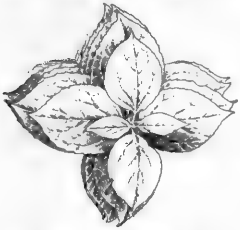

FIG. 52. Top view of vertical shoot of syringa (*Philadelphus*)

The leaves are arranged in pairs, and each pair overlies the spaces between the pair immediately below it. One fourth natural size

Have the veins of the leaf other uses besides their function as conveyers of water? Explain.

69. Alternate and opposite arrangement of leaves. When a leafy apple twig (fig. 51) is compared with one of maple or box elder, it is evident that the former has its leaves arranged in a spiral order, while the latter bears its leaves in pairs. One leaf of each pair is on the opposite side of the twig from its mate, and a leaf of each pair covers the interval between the two leaves next above or the two leaves next below (fig. 52). Leaves borne in spirals are said to be *alternate*, and those in pairs, like maple leaves, are said to be *opposite*.

FIG. 53. Top view of a horizontal shoot from the shrub shown in figure 52

The leaves spring from the branch in the same order as do those of the vertical branch, but by a twisting of the leafstalks the blades are made to lie in a nearly horizontal position, and thus secure abundant illumination. One fourth natural size

The spiral arrangement is much the commoner, being characteristic of most herbs, most shrubs, and very many hard-wood and fruit trees. Some of the most familiar opposite-leaved

shrubs and trees, besides those already mentioned, are the lilacs, the ashes, the horse-chestnut, and the buckeyes. Many kinds of spirals occur, the simplest being that of indian corn, in which the leaves stand in two rows along the stem, the third directly above the first, the second above the fourth, and so on.

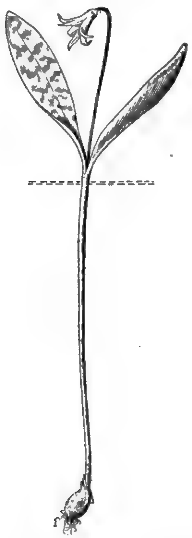

FIG. 54. Entire plant of dog-tooth violet (*Erythronium*)

Hardly any aërial stem appears, the flower stalk being sheathed by the leafstalks and arising from a deeply buried bulb. One fourth natural size

70. Importance of leaf arrangement. The photosynthetic work of ordinary leafy plants is run by sun power, or (to put it more technically) is due to the energy derived from the sun and acting

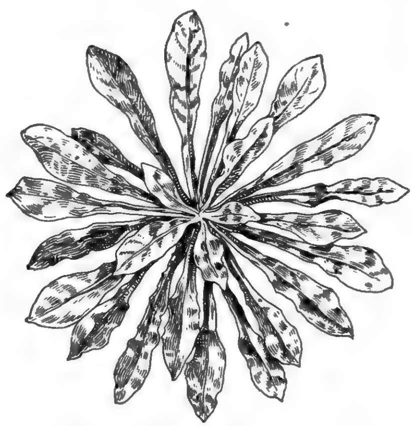

FIG. 55. Rosette of leaves of the common evening primrose, as seen at the end of the first year's growth of the plant

on the green cells of the leaf. Clearly, therefore, it is usually as important for sugar- and starch-making that the leaf should catch all the sunlight it can get, as it is for rapid sailing that a sailboat should expose its sails as fairly as possible to the wind.[1] The student will find it well worth while to observe the arrangement of alternate leaves, which are so placed, both

[1] Leaves just unfolding from the bud, some of those exposed to tropical suns, and certain others (sect. 51) are exceptions.

on vertical and on horizontal branches, that they lie flatways to the sun and do not overshadow each other. The way in which these results are secured in the case of opposite leaves is well shown in figures 39, 52, and 53.

71. Rosette plants. Some plants, such as the dandelion and the plantains, have their leaves spread out in the form of a

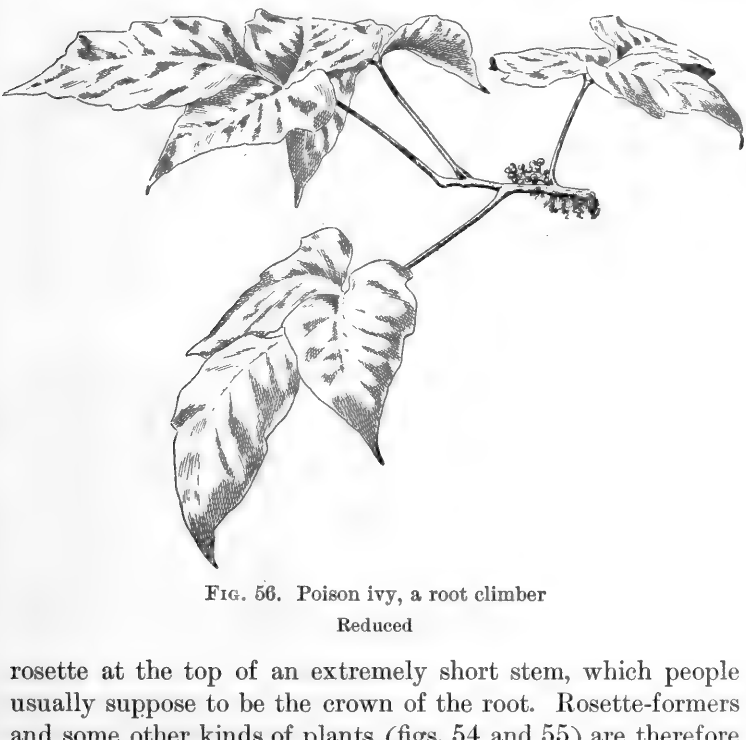

FIG. 56. Poison ivy, a root climber
Reduced

rosette at the top of an extremely short stem, which people usually suppose to be the crown of the root. Rosette-formers and some other kinds of plants (figs. 54 and 55) are therefore often incorrectly said to be stemless. During the first year of growth from the seed a good many *biennials*, like the common evening primrose (fig. 55), beets, carrots, and parsnips, form a more or less perfect rosette crowning a stout, fleshy root. The second year they produce a tall, leafy stem, then blossom and bear seeds. In rosette plants the leaf is usually

narrow at the base and wider at the tip, as in the evening primrose, so that nearly all the space between the leaves is filled in.

During which year of the life of a biennial is its principal work photosynthetic? During which year is it reproductive? Why are beets, carrots, parsnips, and salsify used as food at the end of the first season's growth?

FIG. 57. The wild frost grape, a typical tendril climber

This vine is climbing on an American elm. The height up to the branch *l* is about 60 feet, and the average circumference of the main vine, 3 feet. Redrawn and simplified from a photograph by Robert Ridgway

72. Leaf mosaics. Any combination of leaves (whether found in rosette plants or on longer stems) in which the space is very fully occupied, with few spaces between the leaves, is called a *leaf mosaic*. Walls covered with Japanese ivy furnish beautiful examples of leaf mosaics on a large scale, and many of our common house plants illustrate the same phenomenon. In any leaf mosaic many of the leaves occupy a very different position from that which they would have taken if borne on a vertical stem.

73. Climbing into the light. Many plants, of very diverse families, secure a better exposure of the leaves to light by climbing. The principal types of climbing plants are four in number: *scramblers*, like the common climbing roses; *root climbers*, like the poison ivy (fig. 56) and the English ivy (fig. 40); *twiners*, like the morning-glory; and *tendril climbers*, like the grapevine. The only way in which one can get a thorough knowledge of the behavior of climbers is to watch them throughout as much as possible of the growing season.

The development and mode of operation of tendrils is especially interesting (figs. 58 and 59). The tendril is either a leafless, thread-like branch, as in the grapevine, or a highly modified leaf or part of a leaf, as in the cucumber. When a living and active tendril comes into contact with any suitable

FIG. 58. Bur cucumber (*Sicyos*), a tendril climber

At *a*, *b*, *c*, *d*, *e*, and *f* successive stages in the history of tendrils are shown. The tendril, at first curved, becomes straighter, then curls up at the tip, and finally (after becoming attached to some object) coils itself into a close spiral and thus draws the plant with considerable force toward the sustaining object

support for the climber, this contact brings about more active growth on the exterior side of the tendril (that side which does not touch the foreign object). In this way the tendril is made to coil about the support. Soon after the tendril has become attached, the free portions are thrown into coils, and the shortening which results draws the stem of the climber closer to the support.

74. Excessive illumination. While the leaves of plants growing in the shade often suffer from lack of sunlight and are usually so arranged as to utilize most fully what light there is, it is possible for leaves in exposed situations to have too much light. It seems certain that the most powerful sunlight may injure the chloroplasts and therefore cripple the power of the leaf to do its work of photosynthesis.

Fig. 59. Virginia creeper (*Psedera*), a tendril climber

The tendrils are modified shoots. At *a* they are seen fastened to a twig and at *b* adhering strongly by means of their expanded, disk-like tips to the surface of a wall

Compass plants, such as the common prairie rosinweed (*Silphium*) and the prickly lettuce, have leaves somewhat erect, with edges directed nearly north and south, so that they secure good illumination during the cooler morning and evening hours but present the leaves nearly edgeways to the sun at noon. Many other plants maintain some or all of their leaves in a nearly vertical position, but with the edges not directed north and south. In the olive many leaves point almost vertically upward, while in the commonest species of *Eucalyptus* (fig. 60) the leaves hang vertically downward.

In a great number of trees the young leaves from recently opened buds stand erect or hang straight down. In one tropical species[1] the illumination received by these young drooping leaves is not more than one five hundredth as intense as that received by the most exposed of the mature leaves.

[1] *Amherstia nobilis*, from Burma.

75. Daily movements of leaves. Any one who walks through a clover field at dusk is likely to be struck with the peculiar pale appearance of the leaves, very different from the dark-green color which they have in full sunshine. This paleness is due to the fact that as the daylight fades the leaflets droop, as shown in figure 61, so that little except the under surfaces are seen. A large proportion of the plants of the Pea family and many other plants have leaves that take a special night position. Some leaves, as those of the bean and the black locust, have three positions — one at night, another in ordinary daylight, and a third in intense sunlight. The daylight position is usually almost horizontal; the position for brilliant sunlight is vertical. In the locust the change from vertical to horizontal occurs quickly enough to make it worth while to watch it coming on as the sun moves westward after noon and the leaves are left in the shade.

FIG. 60. Branch of *Eucalyptus*, with leaves hanging almost vertically downward

About one fourth natural size. After Bonnier and Sablon

In plants of the Pea family the daily leaf movements are brought about by means of a sensitive, cushion-like organ, the *pulvinus*, situated at the base of the leafstalk. It is easy to see the use of the horizontal and the vertical leaf position, but the importance of the night position is not so well understood.

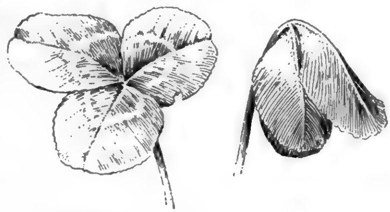

FIG. 61. A leaf of red clover

At the left, leaf by day; at the right, the same leaf at night. Natural size

76. Self-pruning of leaves and twigs. Many trees and shrubs begin to shed some of their leaves even in the spring, very soon after the leaves are well grown. Examples of this are

the lilacs, the syringa (*Philadelphus*), the cottonwood, the horse-chestnut, the box elder, and some lindens. Still more common is the loss of leaves during the summer, which may amount to 30 per cent of the total number of leaves. This leaf fall, coming long before the leaves are cast off in the autumn as a preparation for winter, affects chiefly the leaves inside the crown of the tree, which have such scanty light that they evidently cannot accomplish much photosynthesis.

Fig. 62. The pond lily, an aquatic with floating leaves and submerged stems

Leaves, twigs, and even larger branches which are not getting an adequate supply of light or of water are pruned away by the tree. Were it not for this, the dense growth in the interior of the tree top and along the trunk would soon render further branching mechanically impossible. What one sees on looking up along the trunk into the top of a large tree is mainly dead or dying branches, with few leaves. It is this self-pruning and that due to the shade of neighboring trees that makes the trunks free from knots and most valuable for timber in

trees grown in woodlands, where they stand moderately close together. In some trees — such as the so-called snap willows, the cottonwood, and the large-toothed aspen — live twigs fall very freely during windstorms and snowstorms, and when the tree is loaded with sleet. These twigs may be blown over crusted snow or floated along by brooks or rivers near by, and often lodge in spots where they take root and grow into new trees.

77. Leaves of water plants. Water plants with aërial leaves, like the cat-tails and pickerel weeds, are perhaps the commonest type. Others, like the pond lilies (fig. 62), have floating leaves, with only the upper surface exposed to the air. Still others, like some pondweeds, have all their leaves submerged. There are only a few common plants which have two types of leaf, like the water crowfoot (fig. 63), one set growing wholly in the air and the other set wholly under water.

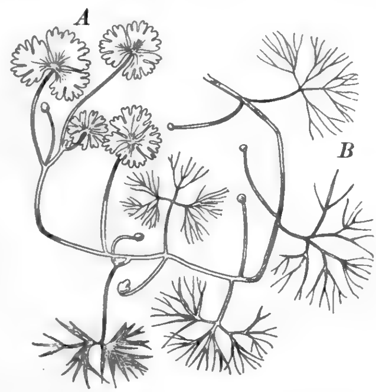

FIG. 63. A shoot of water crowfoot

A, air leaves; *B*, thread-like water leaves. *After* Askenasy

Floating leaves have stomata only on the upper surface; on the lower surface they could serve no useful purpose. Submerged leaves often have the thread-like form shown in figure 63. This form renders them much less liable to injury from waves or currents of water, and also allows the freest exposure of the whole leaf surface to the surrounding water. This offers the best possible opportunity for exchange of gases between the water in which they are dissolved and the interior of the leaf.

78. Size and shape of leaves in relation to water supply. Plants which grow in earth (that is, neither aquatics nor air plants) often show a decided relation between the abundance of the water supply and the amount of leaf surface. Those

kinds which usually grow in very damp soil or in swamps, such as the jack-in-the-pulpit, skunk cabbage, white hellebore, papaw, and some magnolias, are frequently large-leaved plants.

Many plants which grow in extremely dry soils, or in regions where the summer rainfall is scanty or altogether lacking, are characterized by small leaves, often awl-shaped or thread-like. Few familiar examples of such plants with highly reduced leaf surface are to be found among the wild plants of the northern United States.

FIG. 64. The crowberry

This plant has minute leaves with their margins rolled under. It thrives in dry, exposed situations. About one half natural size

FIG. 65. A fleshy-leaved plant (*Mesembryanthemum*) with much water stored in the stiff, clustered leaves

After De Candolle

The crowberry (fig. 64) is one good instance of the kind, and a few weeds of the Pink family, some St.-John's-worts, and some little spurges are other examples. The heather (*Erica*), often cultivated in greenhouses, is an excellent instance of minute, awl-shaped leaves.

Thick, fleshy leaves (fig. 65) are common in plants of desert or semi-desert regions. Some of these leaves are almost cylindrical; others are tongue-shaped; others, like those of the century plant, are thick and broad at the base and taper to a spiny tip. All fleshy, or *succulent*, leaves hold much stored water for use in seasons of drought.

79. Structure of leaves in relation to water supply. Leaves of plants which grow in very moist earth usually have a moderately thin epidermis[1] and are of a rather loose interior structure, with abundant air spaces — even more than are shown in figure 26.

FIG. 66. The giant cactus

This specimen is about 40 feet high. The holes seen in one of the stems are birds' nests. Photograph by the Desert Botanical Laboratory of the Carnegie Institution

The leaves of plants which usually grow in places where they are sometimes in great danger of dying for lack of water commonly have a thick, nearly moisture-proof epidermis and closely packed cells in the interior of the leaf. This insures slow evaporation of whatever water is carried into the leaf, since the thick epidermis prevents rapid drying up of the cells near the exterior, and the scanty air spaces render the circulation of dry air coming into the leaf slow and difficult. Such leaves are often densely covered with hairs, especially on the lower surface, and this coating of hair has been found greatly to hinder the escape of moisture through the stomata.

[1] It is not necessary to discuss here the marsh plants and halophytes treated in works on the ecology of plants.

Frequently each stoma is at the bottom of a depression, or pit, in the epidermis, and is thus somewhat protected from drying currents of air.

80. Xerophytes. Plants like the cactus (fig. 66), the desert *Pelargonium* (fig. 20), the crowberry (fig. 64), and a multitude of others (many of them not marked by any such peculiarities of form and structure as these are), which can resist conditions of extreme drought, are called *xerophytes.* The only way in which one can get a good idea of the difference between xerophytes and ordinary plants, or *mesophytes*, in their power to endure a combination of high temperature and scanty water supply is to compare their behavior under conditions of drought. A potted plant such as a cactus or a houseleek for a representative xerophyte, and a young bean plant or mustard plant for a typical mesophyte, if left unwatered, will afford material for a highly profitable comparison of types.

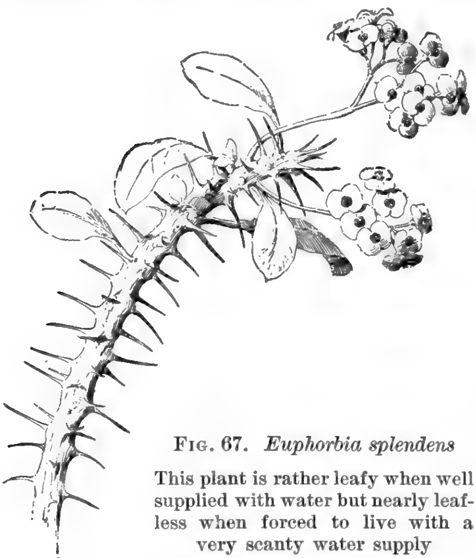

FIG. 67. *Euphorbia splendens*

This plant is rather leafy when well supplied with water but nearly leafless when forced to live with a very scanty water supply

Are any xerophytes of economic value? any mesophytes? any water or marsh plants? Give as many examples as possible.

81. Advantage of shedding leaves. When the soil temperature is nearly at the freezing point, most plants are unable to absorb much water by their roots. It is probably owing mainly to this fact that our ordinary *winter deciduous* trees have their habit of shedding their leaves at the approach of winter. If

their actively transpiring leaves were to remain at work while the ground was almost or quite frozen, the tree would suffer a fatal loss of water.

It has been found that the larch (which sheds its leaves) is more resistant to such conditions than are most of the evergreen conifers, although the latter have leaves of a highly xerophytic type. In a rainless summer some shrubs retain or shed their leaves in proportion to the amount of soil moisture with which they are supplied. The *Euphorbia splendens* (fig. 67) is a commonly cultivated plant which well illustrates this capacity to adjust the amount of leaf surface to a varying moisture supply. In regions like Southern California and the coast of the Mediterranean, where the long, hot summers are nearly rainless, some trees and many shrubs are *summer deciduous*, losing almost or quite all of their leaves at the beginning of summer. Twigs in this leafless summer condition have been found to lose in a given time only about one thirty-sixth as much water as they do when in full leaf.

The shedding of the leaf is a somewhat complicated process; a waterproof layer of tissue is formed at the base of the leaf-stalk, and this cuts the leaf off from communication with the stem. Before this layer is formed, the plant food in the leaf has often been conveyed into other parts of the plant, so that when the leaf falls, it takes with it little of value.

PROBLEMS

1. Show that the roots, stem, and leaves of ordinary trees coöperate to do the work of food-making.

2. Why is it that trees which are left standing after their forest neighbors have been cut away are more liable to injury from windstorms than are those which have always grown in the open?

3. Discuss the various ways of climbing, and show which are generally the most effective in securing a good light supply under great difficulties.

4. From what you have seen, does it seem probable that the different kinds of plants in a piece of woodland all require about the same intensity of light? Discuss this matter, giving examples.

5. Would you expect to find any kind of compass plants in woodlands? Why?

6. Why do most aquatic flowering plants have leaves that are exposed to the air, rather than submerged leaves?

7. Why are trees of the moist tropical regions usually evergreen?

8. May a shrub or a tree be deciduous or evergreen, according to circumstances? Give examples.

9. If you wanted to make a cactus plant produce leaves, how would you treat it? Why?

10. If an aquatic plant were transplanted into desert soil and an extreme xerophyte into a shady swamp, what appearances would in each case soon show that the plant was dying?

11. What mesophytes do you know that can grow under a very wide range of conditions as regards light and moisture? Compare, with regard to their tolerance of drought, some common plants important in agriculture.

CHAPTER VI

SPECIAL FUNCTIONS AND FORMS OF STEMS

82. Stems not always for the support of leaves. In Chapter V considerable space was given to explanations of some of the ways in which stems serve to support leaves in advantageous positions for photosynthetic work. This is not, however, by any means the only function of the stem or portions of the stem. Something was said in Chapter IV about the importance of food storage in stems, and something in section 56 about their work of photosynthesis. Some other important things done by whole stems, or by more or less highly specialized portions of them, will be discussed in the present chapter.

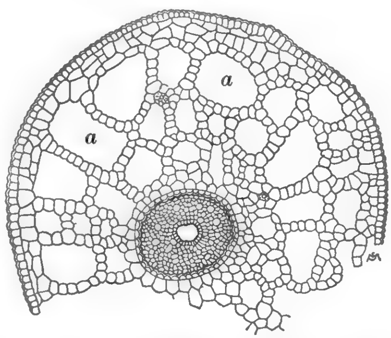

Fig. 68. Cross section of stem of pondweed (*Potamogeton*), showing air passages *a*, much magnified. After Green

83. Storage of air or water in the stem. It seldom happens that the same plant would be benefited by storing both air and water abundantly in its roots or stems; but marsh and water plants may evidently be much aided in their respiration by holding a good deal of air inside the plant body. In some such plants the air passages and air cavities form a complex system, which extends all the way from the stomata to the tips of the roots. A section across the stem of any of the common pondweeds (*Potamogeton*) (fig. 68) shows clearly how large and abundant its air passages are.

Desert plants, or those which for any reason may often be exposed to intensely hot, dry air, are safer without large air cavities anywhere in the interior of the plant, but stored water is of the greatest use to such plants, and it may be found in the roots (fig. 20), in the stem (fig. 66), or in the leaves (fig. 65).

84. Characteristics of underground stems. The popular notion of a stem includes the idea that it is an aërial part of the plant. It is easier to recognize as roots such structures as the aërial roots of corn and of poison ivy than it is to recognize as stems the thickened underground portions of iris, jack-in-the-pulpit, dragon-root, trillium, or potato. Frequently, like aërial stems, underground stems are divided into nodes and internodes; many of them bear scales which represent leaves, and in the axils of these scales they produce

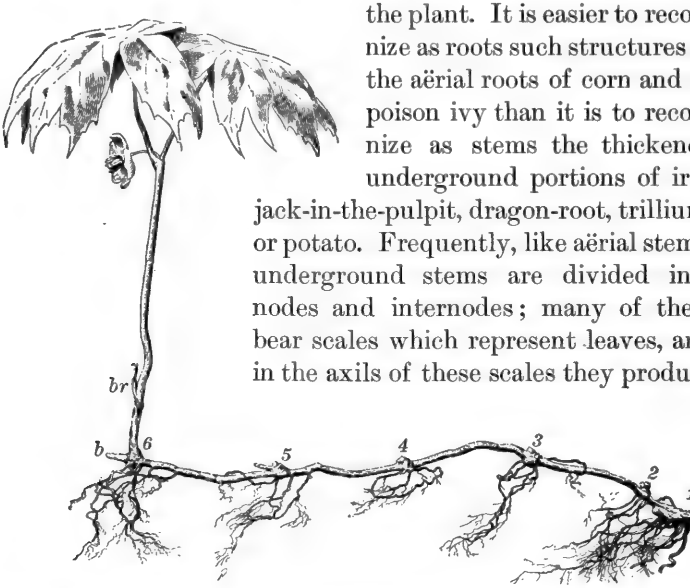

FIG. 69. A May-apple plant, showing the history of the rootstock

1 is the oldest surviving portion of the rootstock; *2* is a year younger; *3* a year younger than *2*, and so on. At each figure the cluster of roots marks the position of the base of the upright stem for that year, as is shown at *6*. *b*, bud for the new year's growth; *br*, bract at the base of the present stem. One sixth natural size

buds. Such buds are well shown in the underground stems of some grasses. Dicotyledonous underground stems usually have distinct bark, wood, and pith; most dicotyledonous roots do not have pith, though some do.

Some of the principal forms of underground stems have for convenience been given special names. The elongated forms,

like that of the May apple (fig. 69), the mints, couch grass, and many other plants, and some stouter kinds, like that of the trillium and Solomon's-seal, are known as *rootstocks*, or *rhizomes*. The very short shoots with disk-like stems and a covering of scales, or of coatings formed by thickened bases of leaves (familiar in some lilies, the tulip, and the onion), are called *bulbs*. Much like bulbs, except that the stem is more developed and that the scales are almost lacking, are *tubers*, like those of the Jerusalem artichoke, the potato, and the crocus.[1] The potato is a particularly good tuber for study, as it has well-defined nodes and internodes; the buds (eyes) are arranged in a distinctly spiral manner and are borne in the axils of little scales which represent leaves, and not infrequently the tuber is considerably branched.

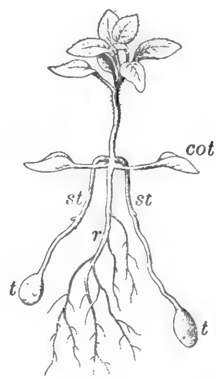

FIG. 70. A potato seedling ten weeks old

cot, cotyledons; *st*, tuber-bearing underground stems; *t*, very small tubers; *r*, root. Three fourths natural size. After Percival

85. Reproduction by portions of the stem. Some plants naturally reproduce themselves mainly by more or less specialized portions of the stem, and in a cultivated state many others are made to do so. There are numerous kinds, such as the potato, the strawberry, the banana, and most lilies, that are almost always propagated by some sort of stem or shoot.

Many plants bear small aërial bulbs or tubers on some portion of the stem and are commonly reproduced by these. Familiar examples among cultivated plants are the onion and the tiger lily. The bulblets known as onion sets are for sale at every seed store, and in some parts of the country are almost exclusively planted by onion growers, while in other sections the seed is more generally planted. The black bulblets of the tiger lily

[1] Such very short underground stems as that of the jack-in-the-pulpit and the crocus are often called *corms*.

FIG. 71. A potato plant grown from the tuber, ten weeks old

o, old tuber; *s*, stems on which young tubers are forming. One sixth natural size. The total space occupied by this plant is much more than two hundred times that occupied by the seedling plant of the same age (see fig. 70)

are borne in considerable numbers along the stem, in the leaf axils, and may be found on the ground, rooting, in the late autumn and the following spring. Some of our common wild plants, including certain ferns, are propagated by bulblets.

Underground stems of various kinds are so common as means of reproduction that only a very few of them need be mentioned. Some of the worst weeds are those which have running rootstocks, like the nut grass (*Cyperus*), which produces many little tubers, each of which may grow into a new plant, and the couch grass (Chapter XX) and Canada thistle, which may be cut up by the hoe and produce a new plant from every node. Among cultivated plants a great number of the earliest blooming herbaceous kinds, such as squills, hyacinths, tulips, crocuses, and snowdrops, are grown from bulbs or other forms of underground stem. The commonest of all instances of propagation by this kind of stem is that of the potato (figs. 70 and 71), which is never grown from seed except for the production of new varieties. As every farmer and market gardener knows, each potato will produce as many new plants as it has buds, or eyes,

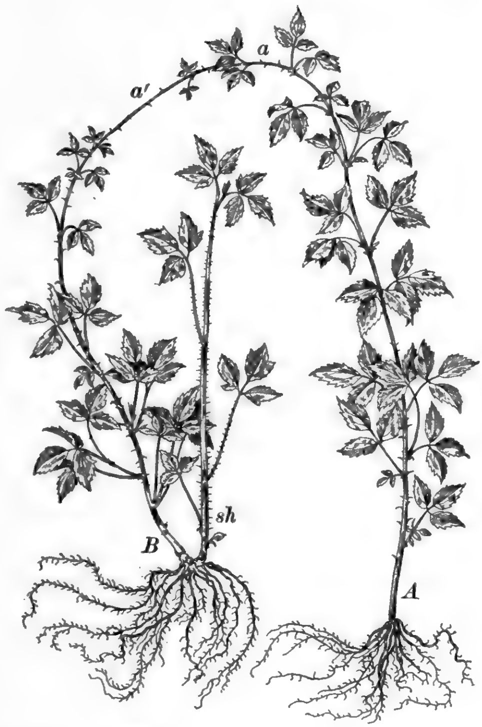

FIG. 72. A black raspberry plant reproducing by a natural stolon

At *A*, the original root system; at *B*, a newly formed root system with a young shoot *sh*. Much reduced and somewhat diagrammatic. The arch is really much flatter and the dying portion of the stem, *aa'*, proportionally five or ten times as long as here shown

though it is better not to cut the potato into too small pieces for propagation, or the plants will grow slowly at first.

Why are potatoes almost always grown from the tuber rather than from seed? Why are plants of the Lily family grown from bulbs?

FIG. 73. A willow cutting

The roots are a little more than two months old. Somewhat reduced

86. Stolons, runners, and cuttings. Some plants, as the black raspberry (fig. 72), are naturally propagated by recurved branches which root wherever they touch the earth. Such rooting branches are called *stolons*. An artificial modification of this process (called *layering*), sometimes made use of in growing apples, pears, plums, and quinces, consists in bending down branches and covering portions of them with earth until they become well rooted.

Runners, like those of the strawberry, are very slender, nearly leafless, stolons.

Cuttings are twigs or branches cut off, set in the earth, and kept there until they become well rooted (fig. 73). Numerous woody plants, such as willows, grapevines, currant bushes, gooseberry bushes, and geraniums, and some herbaceous plants, such as the hopvine and the Wandering Jew, are usually grown from cuttings. Many others, such as the French marigold and the garden portulaca, not usually thus grown, may be readily propagated by cuttings. In the case of woody plants the cutting should be taken from well-matured twigs of the previous season. To avoid wilting, leafy cuttings are often kept covered for a time with a tumbler or bell glass.

87. Budding and grafting. The process of *budding* consists of detaching an uninjured bud from the stem of one plant and inserting it under the bark of the stem of another plant (fig. 74). Peaches and cherries are familiar examples of trees commonly propagated by budding. The operation should be performed at a season when the cambium layer is active, so that the transplanted bud will at once unite with the wood of

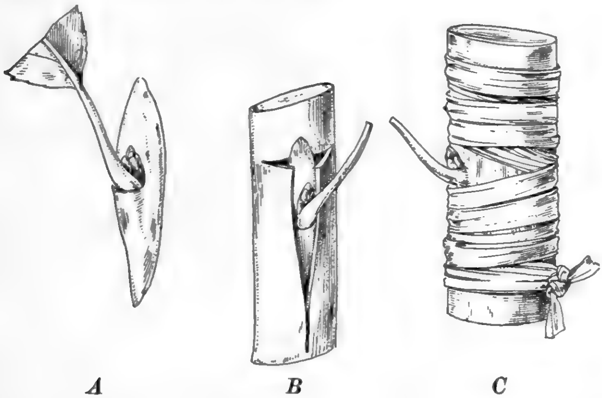

FIG. 74. Propagation by budding

A, a bud cut from a tree of the desired variety, with a piece of the underlying bark; *B*, the bud inserted in a T-shaped slit in the bark of the stock; *C*, the same with the bark bound in place by strips of raffia (a fibrous material obtained from the leaves of the raffia palm). Modified after Percival

the stem into which it is set. In the case of peaches, the young seedling trees grown from seeds planted the same spring are budded in June or September. Those budded late do not grow much until the next season, but then make rapid progress. As the top of the seedling is cut off not far above the bud, all further growth of the shoot partakes of the quality of the bud, and the fruit borne by the tree, when it is large enough to bear, will be of the kind that is characteristic of the tree from which the bud was taken.

Grafting is removing a piece of stem, with its buds, from one plant and inserting it into a portion of stem of another

living plant so that the cambium layer of each will be in contact with that of the other (fig. 75). The plant into which the stem is inserted is called the *stock*, and the portion of shoot which is set into the stock is called the *scion*, or *graft*. There are many kinds of woody plants which may readily be grafted, but the process is of practical importance mainly for the grower of apples and pears. Various plans are adopted in different fruit-growing regions. One of the commonest methods for the propagation of apples is *root grafting*. Seedling trees a year old are dug in the autumn and the roots grafted with one-year-old scions of desired varieties of apple trees, each cut to the length of about six inches. The grafted roots, wound about the joined surfaces with waxed cord, are packed in sand in a cool and not too dry cellar and left until spring. By that time the cambium layers of root and scion have united and the roots are ready to plant. *Tongue grafting* is practiced in the spring either with young seedlings or with twigs of larger trees (fig. 75). *Top grafting* consists in cutting off limbs one or two inches in diameter, splitting for a short distance the portion remaining attached to the tree, and inserting at each part of the split, where it crosses the cut surface, a small scion, and then completely covering all exposed parts with grafting wax. Root grafting has the advantage of resulting in a tree with trunk and branches wholly of the desired variety of apple. Tongue grafting of small branches does not interrupt the growth of the tree and is done with very little trouble. Top grafting is mainly resorted to in order to renew old trees that are not bearing the desired variety of apple.

FIG. 75. Grafting

At the left, scion and stock are shown ready to be united; at the right, they are joined and ready to be covered with grafting wax. After Percival

The student should notice that, while budding and grafting are described as modes of vegetative reproduction, *their object is not to increase the number of shrubs or trees in the garden or orchard.* It is rather a means of propagating the desired kind of plant with certainty — for example, to secure a certain variety of fruit. This cannot be done merely by growing seedling trees, since every seedling grown from any valuable kind of apple or pear may differ from all the others of the same lot (fig. 163), and not one of them be worth cultivating.

Grafting often succeeds on plants of different species,[1] as the peach on the plum, the apple on the pear, and the pear on the quince. Sometimes it succeeds between different genera [1] of the same family,[1] as the tomato on the potato.

Many technical details best learned from a practical horticulturist are necessary in order to bud or graft successfully.

PROBLEMS

1. What common feature would you be likely to find in the structure of the stems of pickerel weeds, cat-tails, and rushes, and in the leafstalks of pond lilies and lotuses?

2. Large cacti in the deserts of the southwestern United States and Mexico are often cut open in order that their sap may be used for drinking water. Where did the plant get so much water? How could it have used the water?

3. What common garden plants are reproduced by bulbs? Can any of these be grown from seeds?

4. Do most kinds of plants grown from bulbs bloom early or late? To what two kinds of climate are such plants suited? Give examples, among both wild and cultivated plants, to illustrate your answer.

5. Could more than one kind of scion be top-grafted on a single stock? Why do top-grafted trees, after they come into bearing, require more careful pruning than ungrafted trees? What kind of fruit will be borne by shoots that arise below a graft?

6. Do bulbs planted in autumn freeze in winter? What are the best methods and times for the outdoor planting of bulbs in your locality? Should different plans be used for different kinds of bulbs?

[1] For the definition of the terms *species*, *genus*, and *family*, see Chapter XIII.

CHAPTER VII

BUDS AND BRANCHES

88. Occurrence of buds. If we look at the live branches of any shrub or tree during the winter, many buds will be found along their sides, and usually each twig is tipped with a bud. Most people are aware of these facts, but they have not generally observed that the formation of these buds began rather early in the summer. It is not usual, among those who are not botanists, to speak of the buds of herbs, such as beans, peas, tomatoes, and cucumbers; and yet such plants are well provided with buds, only they are inconspicuous and often nearly hidden by the young leaves at the tips of the shoots.

FIG. 76. Opening leaf bud of rose

a, *b*, *c*, and *d* show stages of transition between bud scales and fully developed leaves. After Payer

To be accurate we must classify buds into scaly *winter buds* (or *resting buds*) and *naked buds*. The latter occur not only on all herbs (fig. 49) but also on the shrubs and forest trees of hot countries.

Generally speaking, scaly buds occur in woody plants which grow in cold or temperate climates, where such buds are well suited to resist the sudden winter changes from heat to cold, and the reverse. Some of our common trees and shrubs have

buds which are only slightly protected by scales, but these buds are usually small and often more or less hidden under the bark, as in the syringa (*Philadelphus*) and the thorny honey locust (*Gleditsia*).

89. Buds become shoots. If we watch the opening and subsequent growth of a bud (figs. 76, 83, and 84), we shall find that sometimes it develops into a leafy shoot; that is, it forms the beginning of a new twig or lengthens out the twig, branch, or main stem at the tip of which it was formed. Sometimes it develops into a flower or a cluster of flowers. Sometimes it produces both leaves and flowers. Buds, then, are classified, according to the results of their development, into *leaf buds*, *flower buds*, and *mixed buds*. And since a flower (as we shall see in Chapter IX) is only a peculiar kind of shoot specialized for seed production, we may define a bud as an *undeveloped shoot*.

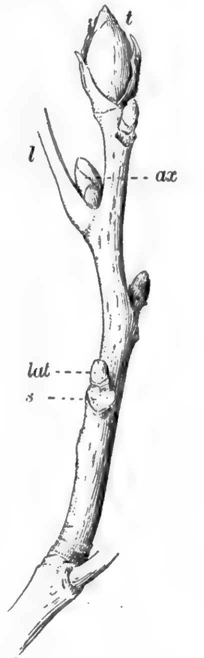

FIG. 77. Twig of hickory in winter condition

sc, scar of last year's leaf; *lat*, a lateral bud: *l*, a last year's leafstalk; *ax*, a lateral bud in the axil of the leafstalk; *t*, terminal bud. Reduced

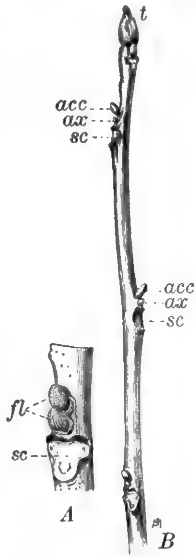

FIG. 78. Twigs of butternut, with accessory buds, in winter condition

A, part of a twig, near a leaf scar, about natural size; *B*, tip of another twig, slightly reduced; *acc*, accessory bud; *ax*, axillary bud; *sc*, leaf scar; *t*, terminal bud. Note the unequal size of the buds in *B*, and the difference in shape between the axillary and terminal buds in *B* (all leaf buds) and the two egg-shaped flower buds, *fl*, in *A*

90. Position of buds. Buds are either *terminal* (growing from the tip of the stem) or *lateral* (growing from its side).

The plumule (fig. 141) is the first terminal bud of the young seedling. Commonly the terminal bud is stronger than any of the lateral ones, and makes more rapid growth than they do.

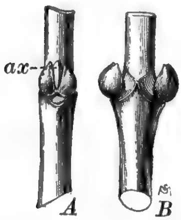

FIG. 79. Accessory buds of box elder

A, face view of a single group, with axillary bud, *ax*, between accessory buds; *B*, profile view of two opposite groups

Lateral buds are usually *axillary;* that is, they arise from the axil, or angle formed by the leaf with the stem, as shown in figure 77, *ax*. Many plants also produce *accessory buds*, that is, buds a little outside of the leaf axil, which may either stand above the axillary bud, as in the butternut (fig. 78), or on either side of it, as in the box elder (fig. 79).

Adventitious buds are those which spring, without any definite order, from roots, stems, or leaves. These are often of great value in propagating plants by means of cuttings or layers.

91. Bud position and branching; form of trees. Plants with alternate leaves bear alternate buds, and those with opposite leaves bear opposite buds. If the buds develop into branches, their arrangement will of course follow the plan of the leaf arrangement. Figures 80 and 81 show the results of one year's growth of twigs from alternate and from opposite buds. Sometimes (fig. 81) the branch is terminated by a flower cluster. In this

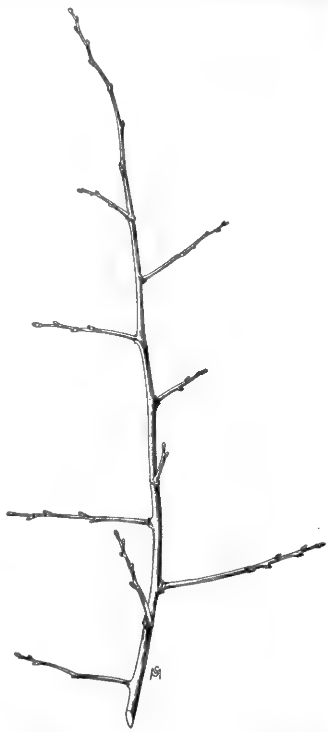

FIG. 80. Alternate branching in seedling tree of cultivated crab apple

case it cannot grow straight on from the tip the next year, but one of the twigs a little farther back will be rapidly developed and will serve to prolong the main branch.

FIG. 81. Opposite branching in privet

The branch is shown as it appeared in March. The growth of the year terminated in a flower cluster, followed by fruit. Since no terminal bud was formed, the continuation of the main branch during the next season would have been by the strong growth of the twig *tw*

If the terminal bud of the main stem continues year after year to be the strongest, the general form of the tree will be somewhat conical, as are larches and spruces; but if some branches grow in length as fast as the main trunk, the tree will become round-topped and spreading, like an apple tree.

92. Competition among buds and branches. Seen from a little distance the top of a tree usually appears like a somewhat conical or hemispherical mass of leafy branches, but on looking along the trunk up into the tree top one sees that the interior of the crown is hollow, nearly destitute of leaves, and with few live twigs on the trunk (except near its upper end) and few on or near the bases of the branches. A very large proportion of all the much-shaded twigs that might be developed into branches during the growth of a tree are actually killed by light-starvation. They cannot do photosynthetic work and are therefore without food.

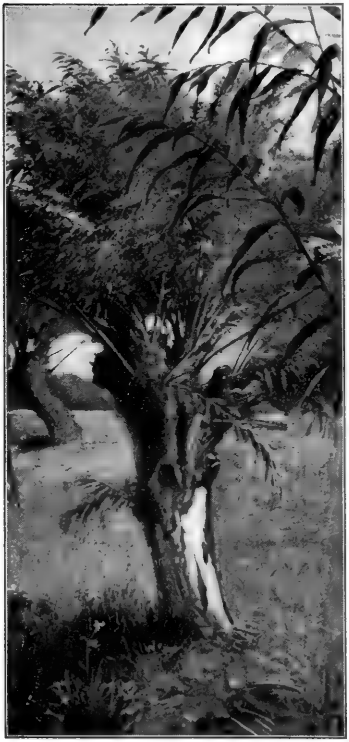

FIG. 82. A pollarded willow sending out many slender twigs from buds which would not have grown if the main branches had not been cut away

Cutting off the top or the main branches of many kinds of trees (*pollarding*) causes buds along the trunk and larger branches to develop into slender twigs, used for withes and for basket-making (fig. 82).

93. Fruit spurs. A *fruit spur* is a short fruit-bearing twig borne on the side of a branch (figs. 83 and 84). Apple, pear, plum, and cherry trees afford capital examples of the production of fruit spurs. At the tip of the spur a flower bud (or a mixed bud) is borne, and this usually develops into a cluster of flowers, one or more of which, under favorable conditions for growth, may mature into fruit. In the apple and the pear (fig. 84), although the

flower bud contains a good many blossoms, only one fruit is generally produced from each bud. In cherries a single bud produces a cluster of fruits. Why?

Fig. 83. Development of leaf bud of pear

A, a leaf bud of pear in autumn; *B*, a leafy shoot derived from *A*, as seen in the middle of the following summer, with flower bud at tip; *C*, the fruit spur *B* as it appears in autumn, after the falling of the leaves

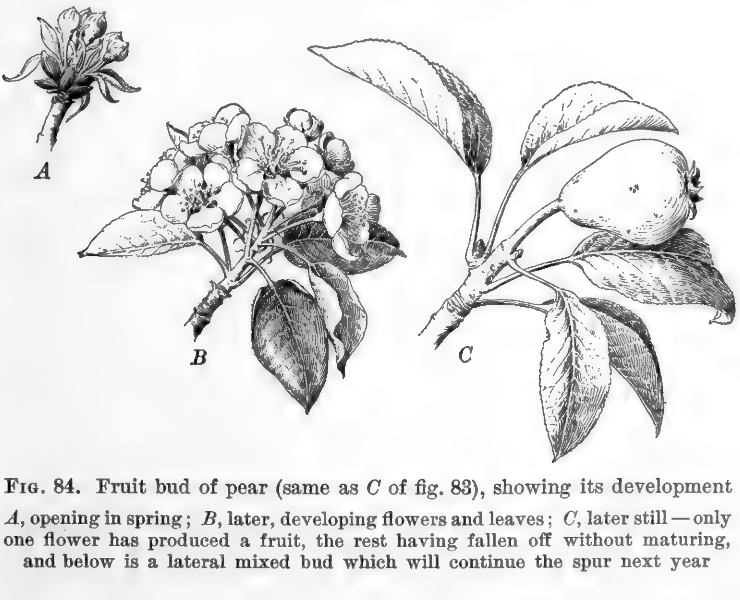

Fig. 84. Fruit bud of pear (same as *C* of fig. 83), showing its development

A, opening in spring; *B*, later, developing flowers and leaves; *C*, later still — only one flower has produced a fruit, the rest having fallen off without maturing, and below is a lateral mixed bud which will continue the spur next year

If the terminal bud of the spur contains leaves as well as flowers, a leaf bud is likely to grow in the axil of one of the leaves and thus provide for the growth of the spur during another year. This process may go on for a good many years.

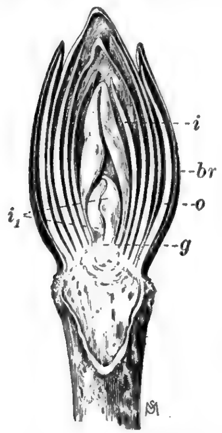

FIG. 85. A lengthwise section of bud of thorn tree (*Cratægus*)

br, brown outer bud scales; *o*, pale bud scale; *i*, innermost rudimentary leaves; *g*, growing point at apex of twig, consisting of cells in a condition to sub-divide and multiply rapidly at the beginning of the growing season. Somewhat magnified

Evidently, when the spur produces a terminal bud containing flowers, it cannot grow straight ahead but must turn aside somewhat. A little study of the age of fruit spurs, made by cutting across them and counting the rings of growth, shows that they increase in length very slowly. This must be the case, since much of the plant food used by the spur is expended in producing the flowers and fruit. The flower scars on an old fruit spur are not all alike, some being much larger than others. This is because the smaller ones mark the places where flowers were borne but no full-grown fruit was matured, while the ones that bore successful fruit are larger and more sharply defined.

FIG. 86. Twig of cottonwood with buds in winter condition

b.sc, bud-scale scars. Two thirds natural size

What would be the effect on the growth of a young tree if all the fruit spurs or buds that produce them were pruned away year after year?

94. Structure of winter buds. The scaly buds of our common trees and shrubs are readily picked to pieces as soon as they begin to swell in early spring, but it is easier to distinguish the parts of which they are composed by watching the opening process from the very beginning. Sections of buds, if carefully made, show very clearly the relations of the parts (fig. 85). In a leaf bud there are, on the outside, the leathery bud scales; inside of these are rudimentary leaves;

FIG. 87. Cottonwood twigs, April 15

The flower buds on the lower twig (developing into catkins) are fully open, but the leaf buds are still closed. Reduced

and within and below the leaves is a central axis tipped with a *growing point* composed of rudimentary cells capable of rapid division and growth.

The scales which cover buds are often the dwarfed and otherwise modified leaves or leafstalks, as is well shown in some buckeyes and in roses in which the opening buds present a series of gradations between mere scales and foliage leaves (fig. 76). In other cases, as in oaks, beeches, lindens, and magnolias, the scales represent the appendages (*stipules*) found at the bases of many leaves. Frequently bud scales are covered with a dense layer of hairs or down, and sometimes, as in

some of the poplars and the horse-chestnut, they are cemented together by a resinous varnish. These coatings of somewhat cold-proof and water-proof materials increase the value of the scales as a protection against sudden changes in the weather during the colder months.

In mixed buds the flowers are usually inclosed by the leaves and develop first (fig. 84, *B*).

95. Opening of buds. Long before winter buds are ready to open they usually begin to swell, and this increase in size may continue through several months. The actual opening sometimes goes on rather rapidly, the scales being shed in such numbers as almost to carpet the ground, as they do, for example, in beech woods. The rudimentary flowers are generally much more sensitive to cold than the young leaves are, as every fruit grower knows. Flower buds are not so likely to be injured by continued cold weather as by severe frosts coming after the buds are partially open. On this account the growing of fruits which are not very hardy (such as the peach) is safest in those parts of the Northern states where the spring comes on late and without interruptions. Parts of the eastern shore of Lake Michigan are for this reason well adapted to peach growing. Damage to buds often comes rather from sudden changes than from extremely low temperatures.

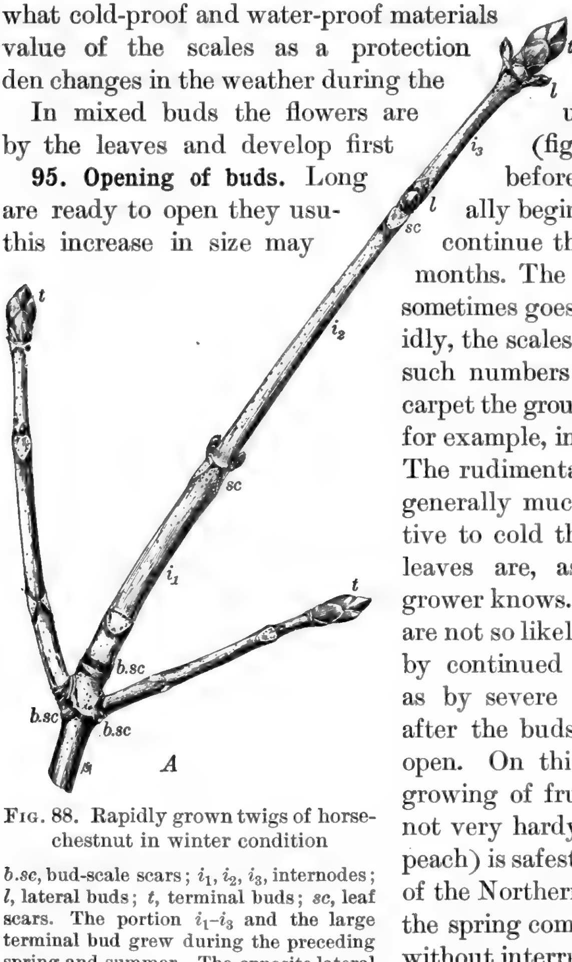

FIG. 88. Rapidly grown twigs of horse-chestnut in winter condition

b.sc, bud-scale scars; i_1, i_2, i_3, internodes; *l*, lateral buds; *t*, terminal buds; *sc*, leaf scars. The portion i_1–i_3 and the large terminal bud grew during the preceding spring and summer. The opposite lateral twigs are of the same age as the portion i_1–i_3. One third natural size

96. The record borne by the twig. In most cases the twig bears upon its surface and in its rings of wood a fairly complete record of the most important events of its life (fig. 90). Some of the markings on the surface of a twig which enable us to make out its history are (1) bud-scale scars (from leaf buds), (2) fruit scars, (3) leaf scars. Other markings are found which tell less of the life history of the twig than those just enumerated, but which should also be considered, namely, (4) lenticels.

The bud-scale scars, as the name implies, are the markings (figs. 86 and 88, *b. sc*) left by the falling of the scales when the bud opened. Plants like geraniums, with naked buds, do not show such scars. As the twig or branch in most cases is prolonged by the growth, spring after spring, of its terminal bud, each ring of scars marks the beginning of a new season's growth. In many trees it is easy to determine the age of twigs or branches by counting the number of such rings (fig. 89). The distance between the rings of scars depends upon the rate of lengthwise growth of the shoot; this varies all the way from a fraction of an inch to ten feet or more per year.

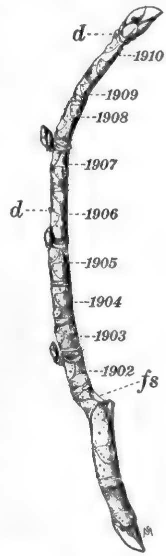

FIG. 89. A slowly grown twig of horse-chestnut in winter condition

d, dormant buds; *fs*, flower-cluster scar. The internodes are numbered in succession (beginning at the bottom) with the respective years during which they were formed. One third natural size

1. How many times greater was the rate of growth of the central twig in figure 88 than the average yearly rate of figure 89?

2. What was the cause of this rapid growth? (Examine a horse-chestnut tree.)

3. If the twig in figure 89 grew unequally in different years, what is a probable cause of the fact?

4. How did the leaves of figure 88 compare in size with those of figure 89? Why?

5. Which bud of each year's growth is usually strongest?

6. How many wood rings would a cross section of figure 88 show at i_1? at i_2? at i_3? Why would these rings differ in size?

7. What would have been the effect upon the wood rings of figure 88 of pulling off most of the leaves above *b. sc* as fast as they appeared?

97. The record; fruit scars. Fruit scars of the same species are often quite unequal in size, the smaller ones marking the positions of unsuccessful fruits and the larger ones of fruits which grew to maturity. Sometimes in mixed buds the young flowers may be destroyed by frost as the bud opens, and in that case it develops much like an ordinary leaf bud, leaving no fruit scar.

In order to learn just the course which a bud follows during its development throughout a year or more, it should be marked by tying a bit of twine or winding a bit of fine copper wire very loosely just above or below it. Sketches like figures 83 and 84 should then be made and notes taken from time to time, whenever decided epochs in the history of the bud occur.

98. The record; leaf scars. Among the most prominent markings on a twig several years old are the roundish, or horseshoe-shaped, areas known as leaf scars (figs. 77 and 78, *sc* and 90, *sc*). These mark the positions where (at the base of each leafstalk) a waterproof layer was formed when the leaf was shed (sect. 81). Some of the things which can be learned from the study of leaf scars are the number, position, and arrangement of leaves on the shoot for several years back, the relative sizes of the leaves, and the mode of bud-bearing of the species studied — that is, whether there were accessory buds or whether the buds were all axillary. On careful examination of any large leaf scar, as that of the ailanthus, the horse-chestnut, or the coffee bean, it is seen to be dotted with a considerable number of minute projections. These mark the course of the fibrovascular bundles from

the leaf into the stem. In dicotyledons there are usually about as many such dots on the scar as there were principal veins in the leaf or leaflets of a compound leaf. Why?

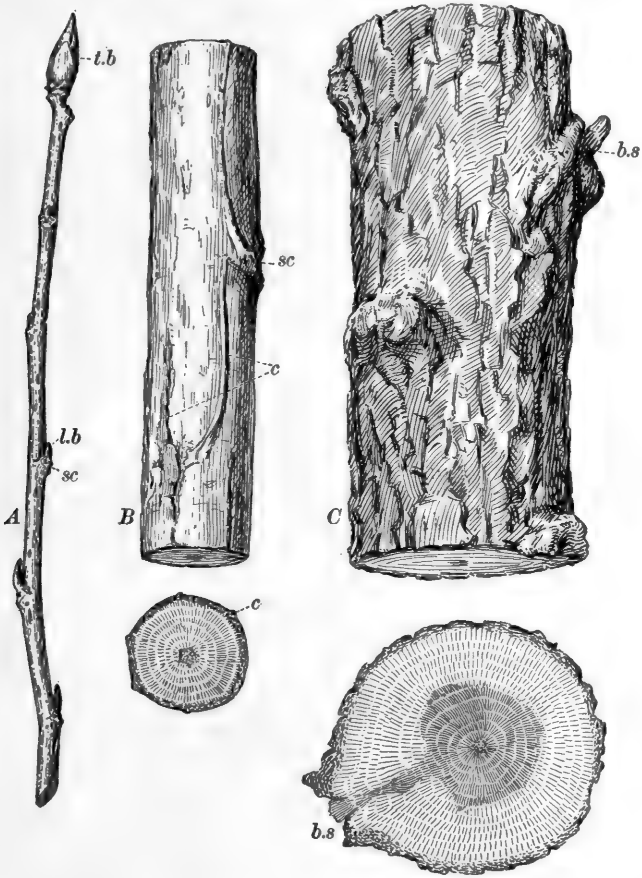

FIG. 90. Development of bark on cottonwood branches

A, young twig showing terminal bud *t.b*, leaf buds *l.b*, and leaf scars *sc*, the bark being almost smooth except where lenticels appear; *B*, an older branch in longitudinal and transverse view, showing the bark *c* as it begins to be broken and ridged, and the leaf scar *sc*; *C*, still older branch, showing the bark after it has become decidedly ridged, and also a branch scar *b.s*.

In tree-like monocotyledons the leaves are not shed as they are by the common trees of temperate climates. Frequently the leaves persist for years but finally decay and leave the trunk of the tree covered with a rough coating formed by the persistent bases of the leafstalks, as is the case with the date palm and many other kinds of palms.

99. Lenticels. Along the twigs and younger branches of most trees and shrubs there are found many dots or larger areas of rough, spongy bark. These are called *lenticels.* They are especially distinct on the bark of most birches and cherry trees, and in these finally reach a rather large size. Each lenticel covers the position originally occupied by a stoma in the epidermis of the very young bark. As the stoma grew older its characteristic cells disappeared and were replaced by a spongy mass of thin-walled cells. The lenticels serve for the entrance of gases into the stem and for their passage out of it, and the respiration of the stem is considerably aided by the readiness with which an exchange of gases goes on through these porous spots.

CHAPTER VIII

TIMBER; FORESTRY

100. Wood as a structural material.[1] There are a few disadvantages in the use of wood for many purposes of construction. Wooden fences and buildings are easily destroyed by fire. Wooden posts, bridges, and similar structures, and shingled roofs, are subject to rather rapid decay. Most woods will not stand long-continued friction without wearing out, so that many of the working parts of machines, when made of wood, as they often were by the early settlers in this country, were short-lived.

Some of the advantages of wood for constructive purposes are as follows:

1. Wood is far cheaper than metals; bulk for bulk, it does not, on the average, cost more than one thirtieth as much as iron or steel.

2. Wood is much more easily worked than metals.

3. Weight for weight, some wood is stronger than iron or steel. A bar of hickory will stand a stronger pull lengthwise than one of wrought iron of equal length and weight. A block of the best hickory or long-leaf pine will bear, without crushing, a greater load than a block of wrought iron of the same height and weight.

4. Wood is light and is therefore much more convenient than metals for many purposes of construction, as building vehicles and making packing cases and tool handles.

5. Wood is a poor conductor of heat and on this account is valuable in the construction of houses, railway cars, refrigerators,

[1] See Roth, First Book of Forestry, pp. 232–238. Ginn and Company, Boston.

and other things. Even in buildings or sailing craft composed largely of steel it is therefore found highly desirable to make the floors, decks, and much of the interior construction of wood.

6. Wood is a poor conductor of electricity. This makes it far easier to manage electric wiring in houses or other buildings in which the floor joists and most of the interior finish are of wood than it is in metal structures.

7. When properly finished, wood usually has a highly ornamental surface. This makes it possible to give to the interiors of rooms, railway cars, and street cars a decorative effect which could be obtained with other materials only with much difficulty and expense. It is not easy to imagine how beautiful furniture of moderate price, such as is made from our ornamental woods, could be made from any metal.

101. Wood as fuel. At present coal is the fuel used in most great manufacturing operations, but the world's coal supply is limited and seems likely at no very distant day to become exhausted. The wood supply, with suitable care, can be continually renewed, and wood will probably always remain, as it is now, an important portion of the fuel resources of the world. The fuel value of wood depends somewhat upon its weight per cubic foot, so that such heavy woods as hickory, sugar maple, ash, beech, and most oaks are worth more for heating purposes than such light woods as willow, cottonwood and other poplars, and most pines and other coniferous woods. Charcoal is used a good deal as a smokeless fuel and is the main combustible ingredient in gunpowder.

102. Coniferous woods. Our native woods [1] are best classified into two principal groups — hard woods and soft woods, or coniferous woods.[2] The needle-leaved, or coniferous trees of the country furnish more than three quarters of our timber supply.

[1] "Timber," *Bulletin 10*, Division of Forestry, U.S. Dept. Agr., 1895.

[2] Some of the needle-leaved, or coniferous, trees, such as the larch and the yew, have rather hard wood, and some broad-leaved trees, such as willows, poplars, tulip trees, and buckeyes, have soft wood; but people who deal in timber usually speak of the two general classes as explained above.

The structure of coniferous wood — as seen, for example, on the end of a beam cut off squarely, or on a new lead pencil — is in one respect less complex than that of most hard woods: the wood is chiefly composed of *tracheids* — long, tubular cells with tapering ends — and contains no continuous ducts, though it may contain resin passages. The rings plainly seen on the cross sections of some kinds are due to the difference in diameter between the tracheids formed in early spring and the later ones (fig. 91).

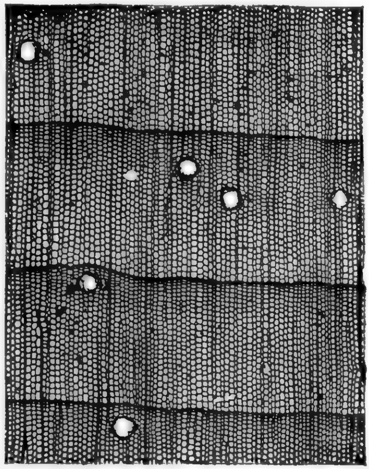

FIG. 91. Cross section of white pine, a typical coniferous wood

a.r, boundaries between one year's growth, or annual ring, and the next. The large, roundish white spots are resin passages that have been cut off. Magnified 15 diameters. Photomicrograph by R. B. Hough [1]

103. Hard woods. Most of the hard wood used for all kinds of construction in this country is furnished by native trees. Of these we have about eighty kinds, the most important ones being the oaks (of about nineteen species). These furnish more than half of our supply of hard-wood timber. Tulipwood, or yellow poplar (*Liriodendron*), is used in great quantities for the interior finish of houses and in the manufacture of woodenware. The wood is soft, free from knots, and furnishes very wide boards. It is not durable when exposed to the weather.

Other important hard woods are ash, beech, birch, chestnut, elm, maple, red gum, and sycamore. Each of these woods has its valuable qualities and its defects, well known to builders

[1] From "Handbook of the Trees of the Northern States and Canada," written and published by Romeyn B. Hough, Lowville, New York.

and other workers in wood. Some woods not among the most important kinds for general purposes are particularly well suited to special uses. Hickory is valuable for ax handles and for wagon and carriage spokes; beech, for shoemakers' lasts, saw handles, and carpenters' planes; black locust and chestnut, for posts and railroad ties, because they decay very slowly even when underground.

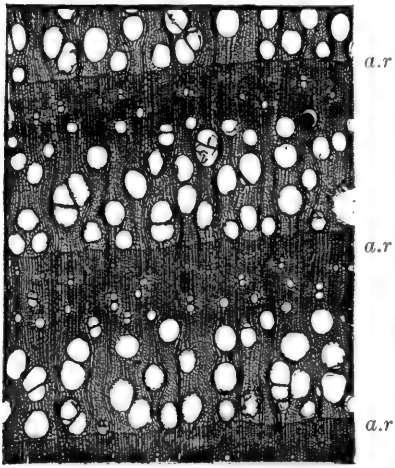

FIG. 92. Cross section of ring-porous wood of sassafras

a.r, boundaries of the annual rings; the wood is ring-porous because the ducts (here shown as oval or roundish spots) are most abundant in the spring wood but almost lacking in autumn wood. Magnified 15 diameters. Photomicrograph by R. B. Hough

Our best native woods for cabinetwork are black walnut, maple, cherry, birch, and some kinds of oak and ash. Red oak is not so strong as white oak, but it has a much coarser grain, so that quartered red oak (cut radially from the log) is among the most ornamental of moderate-priced woods for cabinetmaking and for paneling in the interior finish of houses. Sycamore and sweet gum are also very effective for interior finish, the former being especially important; the supply is very large, and extremely wide boards can be cut from its immense trunks. Large portions of the trunks of old black-walnut trees are often very beautiful in their structure and are extremely valuable, as are also the trunks of bird's-eye maple.

What hard woods used as fuel do you know by sight? What kinds used for construction or other mechanical purposes do you know? What kinds are most readily distinguished from all others? Why?

104. Meaning and importance of forestry. Forestry is the art of forest management. It should be based on the scientific study of woodlands. This study covers all such topics as the distribution of forests over the earth's surface, their dependence on soil and climate, and their own influence upon these. It also discusses their composition as plant communities, their progress from infancy, through youth and maturity, to old age, and their relations to the animal world. The utility

FIG. 93. A prostrate log of sycamore which has lost its bark by decay

Note the extraordinarily twisted grain of the trunk. If this log had been sawed into lumber, it would probably have shown an unusual grain and would have been very valuable for interior finishing

of forests as sources of timber is a most practical forestry topic which stands foremost in the estimation of the public.

Forestry is so extensive a subject that in a portion of a chapter like the present one only a few of its most important sub-divisions can be briefly discussed. Every well-informed person should know, at least in a general way, what forestry is, since the maintenance of some of our best timber lands, and the planting of trees in the prairie and plains region, have become essential to the preservation of the soil and the keeping up of the supply of timber. For about two hundred years one of the chief problems of the pioneer farmer in North America

was to devise ready means of getting rid of the trees which covered the land (fig. 94). A large part of the territory extending east and southeast from the Great Plains region to the Atlantic and the Gulf of Mexico was forest-covered. Now that these immense primeval forests have been destroyed, never to be renewed in their original luxuriance, we are coming to realize that in removing them the early settlers put an end to an almost unlimited source of income, and greatly injured the soil and climate of large areas. Some of the land had to be cleared in order to make tillable fields to grow breadstuffs for the earliest settlers, but it is unfortunate that the clearing process was so well-nigh universal.

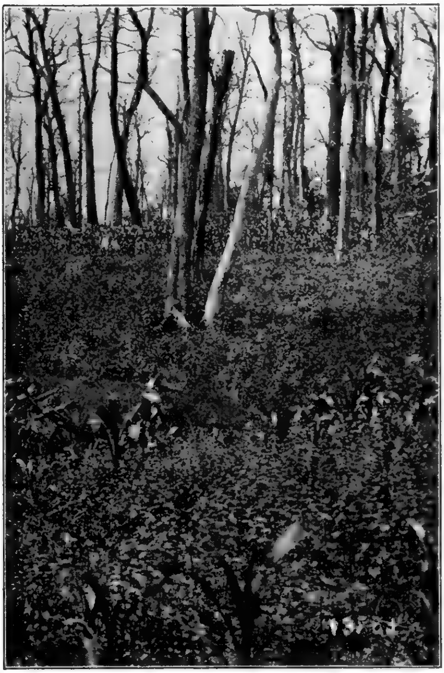

FIG. 94. A "deadening"; trees killed by girdling near the base to clear the land for corn

Photograph by United States Forest Service

105. Pure and mixed forests. Some forests are composed almost entirely of a single kind of tree, like the long-leaf pine growth of figure 229. A few of the hard-wood trees, as the birches, oaks, and maples, are not infrequently found growing nearly unmixed with other trees. More frequently, however, two or more kinds of conifers grow intermixed in the same forest, and the hard-wood trees are still more likely to occur with several kinds associated. Thus we find in the same

group oaks, elms, and ashes; in another, oaks and hickories; in another, beeches and maples (fig. 95). Along the fertile river bottoms of the Middle West one may often find a combination of sycamores, oaks, ashes, black walnuts, elms, and hackberries.

106. Tolerant and intolerant trees. A tree which can endure a good deal of shade is said to be *tolerant*. Examples of this are the hemlock and red spruce, among conifers, and the beech and maple, among hard woods. Trees which require much light are said to be *intolerant*. Examples are the white pine and the larch, among conifers, and the oaks, hickories, and chestnuts, among hard woods. As a rule, seedlings require far less light to begin life than is needed to enable the mature tree to reach its maximum size. So it often happens that seedling trees may survive for years on the forest floor, making but little growth until the decay and fall of overshadowing trees, their destruction by wind, or their removal by the lumberman enables the seedling to grow rapidly into a large tree.

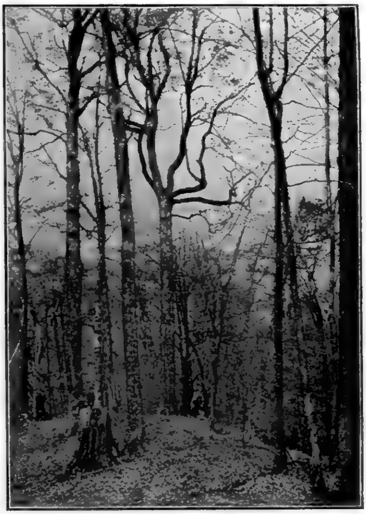

FIG. 95. Primeval deciduous mixed forest of maple and beech

The relative tolerance of trees is an important topic in practical forestry, since the succession of forest growths often depends largely upon this factor. White-pine seedlings could not be made to grow under a good stand of pine or hemlock timber, but young hemlocks or red spruces would succeed there. On the other hand, white-pine seedlings can grow in an aspen forest, and white oak and maple seedlings can grow in an oak-maple forest.

107. Problems of forestry. Most of the questions which the practical forester has to consider can be grouped under three heads:

1. How to establish forests on areas naturally treeless or on tracts of perfectly cleared land.

2. How to maintain existing forests for an indefinite period in the most productive condition.

3. How to fell timber and remove it with the least possible damage to the trees that are left standing.

In a book on general elementary botany only a few hints on these most important topics can be given. Every intelligent citizen, however, should at least know that the conservation of our forests is highly essential, and should understand the general bearing which it has on our welfare as a nation.

108. Forest plantations on treeless land. In such treeless regions as the prairies and the Great Plains it is often desirable to establish belts of timber or considerable tracts of woodland. This is done partly for shelter from winds and partly for the timber produced for local uses. The seeds may be planted where the trees are finally to stand, or young seedlings may be procured from a forest nursery. The latter plan is the better, and it is well to have the young seedlings transplanted once or twice before their final planting, to avoid the formation of long roots, the cutting off of which would check the growth of the tree. Both coniferous and dicotyledonous trees are much planted. Some of the most generally available conifers are the white pine, the Scotch pine, the Austrian pine, and several kinds of spruce. Among the desirable dicotyledons are cottonwood (fig. 96), silver (or white) maple, green ash, honey locust, hardy catalpa, red oak, and (in the warmer parts of the country) eucalyptus. In climates such as that of the lowlands of California, *Eucalyptus globulus* is the most rapid growing of hard woods, reaching a diameter of one foot and a height of one hundred twenty-five feet in ten years. To reach this diameter the white oak would require a hundred years.

109. Propagation of trees in woodlands. Many kinds of forest can be so managed that the young trees sown by natural agencies suffice to keep up the stand when the largest trees are felled (fig. 97). The seeds of most conifers are readily carried considerable distances by the wind, and those of many broad-leaved trees, as birches, elms, ashes, maples, and others, are carried in the same way. Squirrels carry many nuts and acorns and often bury them where they can grow. Many birds — for example, the bluejays — carry acorns, and most fruit-eating birds disseminate such seeds as those of the red cedars, wild cherries, hackberry, mulberry, and a few other trees, often carrying them many miles. Tolerant seedlings may establish themselves in the shade of full-grown trees.

FIG. 96. Part of a windbreak of cottonwood, ten years old

Trees planted 5 ft. × 6 ft., thinned to 6 ft. × 10 ft. The trunks will make good lumber, as the lower branches will all be killed by the shade. Photograph by United States Forest Service

The expense of planting seeds or setting out young trees in woodlands is usually so great as to make it unprofitable, since the natural growth will renew itself with a little artificial aid. It is, however, important to clear away undershrubs that are overshadowing desirable seedling trees.

FIG. 97. Young pines starting in partial shade of hard-wood trees
Photograph furnished by Connecticut Agricultural Experiment Station

FIG. 98. Evergreen windbreak of *Eucalyptus* sheltering a California lemon orchard

Photograph by United States Forest Service

Many trees, as oaks, chestnuts, and birches, sprout freely from the stump, and in this way woodlands that have been cut away are renewed much more quickly than they could be by the growth of young trees from the seed. Often it is found

most profitable to allow the sprouts to grow only twenty or thirty years, forming a *coppice woodland*, which is then cut and used for fuel and for making telegraph poles, fence posts, and railroad ties.

110. Tree belts and wood lots as windbreaks. Every one who has observed the conditions in a country partly wooded and partly cleared knows how much less severe is the effect of winter winds in areas protected by neighboring woods. Cattle that are allowed to range out of doors during cold weather always resort to the lee side of wood lots for shelter. Most orchards and many crops, such as winter wheat, are greatly protected from the effects of destructive cold winds in early spring by the presence of trees on the windward side.

Damage from storms which would blow down corn or lodge small grains may be almost entirely prevented by suitably placed tree belts. It has been computed that a single storm in 1862 damaged standing corn in Illinois to such an extent that the loss was almost great enough to have paid for planting four miles of tree belts on every square mile of land affected by the storm.

Hot, drying winds which parch the crops, and those which blow drifts of fine earth or sand from field to field, may be made far less injurious by patches or belts of trees.

For these and other reasons it has been found highly profitable in many of the comparatively treeless states to plant wood lots and belts of trees in such a way as to afford a supply of timber and at the same time protect the cattle and crops of the farm. The kinds of trees planted vary with local conditions. In general, when protection from winter winds is needed, in all the Northern states the belts should consist partly of evergreen conifers.[1]

111. Regulation of the water supply by forests. It is not fully known just how much influence forests exert on the temperature and rainfall of temperate regions. On this account

[1] See Bates, "Windbreaks," *Bulletin 86*, Division of Forestry, U. S. Dept. Agr., 1911.

it has been possible for people interested in lumbering to assert that clearing off the forests may do no harm to the climate of the country. No one should be deceived by such arguments, since it is a well-ascertained fact that *the water supply of any region is made far more irregular by the removal of its forests.* The annual rainfall may not be greatly changed, but the rivers of a deforested country are likely to overflow their banks after all heavy rains, and then almost disappear during the driest part of the summer. A notable example of this summer shrinkage in rivers is that of the Susquehanna; in 1816 it was estimated that this river delivered five hundred million gallons per day at its season of minimum flow; in 1874 this had shrunk to less than half the amount, although the annual rainfall remained about the same.[1] Every one who has lived in a prairie country knows that the run-off from grasslands is so rapid that creeks which, during a dry time, consist merely of a series of pools may be running bank-full after an hour or two of heavy rain. From plowed land the run-off is even more rapid than from grass-covered land. It is difficult to ascertain just what proportion of the total rainfall is temporarily held by the forest floor. On careful observation of a wooded basin in the Cévennes Mountains in southern France, in which somewhat more than 50 per cent was forest, it was found that after two days of heavy rain more than eight ninths of the total rainfall was held by the soil; water so held may then run away gradually.[2]

The action of forests in retaining water and slowly distributing it is largely due to the following causes:

1. Snow melts gradually in the shade of forests, and so the water derived from its thawing is given off little by little.

2. Evaporation goes on slowly in the shade.

3. The forest floor is often covered to a considerable depth with a layer of highly absorbent material, such as decaying

[1] See Fernow, "Forest Influences," *Bulletin* 7, Division of Forestry, U. S. Dept. Agr., 1893.

[2] Ibid.

leaves and branches. Not infrequently it is covered with moss. The soil of the forest, abounding in humus, retains water much longer than average soil in open fields. All of these factors coöperate to hold back the run-off from wooded areas. It is therefore of the highest importance that such regions as the White Mountains,[1] the Adirondacks, the central and southern Appalachians, and western mountain ranges which are used as sources of water for irrigation should be forested.

112. Forest growth prevents erosion. Along with the value of the forest in regulating the flow of streams, account must be taken of its importance in preventing the washing away, or *erosion*, of the earth's surface. Not only mountains and hillsides but cultivated slopes everywhere are subject to great losses by washing during thaws after snows and during rainstorms. How much earth is thus annually carried to the Gulf by the Mississippi alone has already been stated (sect. 24). Figure 239 represents an early stage in the formation of gullies on a steep slope after clearing. The land is already past the stage in which it can be cultivated in the ordinary way. Left to itself the tendency is for the washing to continue until the hillside becomes a series of miniature ravines, strewn with bowlders and separated by bare ridges. Thousands of acres in the southern United States and hundreds of thousands in some of what were once the most fertile parts of southern Europe have been ruined in this way. Such destruction may be prevented by retaining hillsides in a wooded condition, or at least by leaving belts of trees at intervals, running at right angles to the lines of slope. The early stages of erosion may be checked by damming the principal gullies with logs, stones, and brushwood, and then replanting with suitable

[1] Recent investigations in the White Mountain region by the United States Geological Survey show that the run-off on two drainage basins, each of about five square miles, on the Pemigewasset River, was very unequal. One basin was covered with virgin forest; the other had been deforested and burned. The run-off from the latter basin during seventeen days in April (including three extensive storms) was about double that from the forest-covered basin.

trees and bushes. Contour plowing (that is, plowing around the hill instead of up and down it), terracing, ditching at right angles to the lines of slope, and underdraining, all help to prevent erosion.

113. Rules for forest management. For a detailed account of the mode of keeping up the productiveness of woodlands and of handling timber one must go to special treatises on forestry.[1] In this place there is room to name only a very few of the things to which the forester, or manager of timberlands, must attend.

1. A *timber forest*, or woodland, consisting in considerable part of full-grown trees, should be cut over on a selective plan; that is to say, only those trees should be felled which are nearly or quite full-grown, or which are too much crowded or in some way imperfect or diseased. This kind of selection may not be possible in case the location of the forest is rather inaccessible, and therefore large gangs of men must be taken into the woods and the cutting all done within a limited season. As far as possible the felling must be so managed that promising young trees are not barked or otherwise injured by the falling trunks of the trees which are cut.

2. In managing coppice woods the trees must be cut as soon as they reach a merchantable size — usually in from twenty to forty years.

3. During the period of most active growth all woodlands should be kept covered with a reasonably close stand, so as to secure self-pruning and to discourage the growth of much-branched trees, like those shown in figures 99 and 219, which, when cut into lumber, will be very full of knots.

4. Forest fires must be prevented, especially in woods of coniferous trees. No fires for any purpose should ever be kindled during dry weather in the heart of such woodlands, except in moderately large clearings that are free from brush. Cutting up large tracts of forest into smaller portions by

[1] For elementary principles, see Roth, First Book of Forestry. Ginn and Company, Boston.

means of roads helps to keep small fires from spreading, but in warm dry weather a coniferous-forest fire under full headway makes such leaps that it is seldom stopped until it reaches extensive clearings or rivers or other large bodies of water.

FIG. 99. Oak trees growing in the open
White oak at the left and red oak at the right

5. Parasitic fungi and the saprophytic kinds which cause the decay of fallen trunks and branches or felled trees (figs. 182 and 199) should be burned, when this is not too expensive and when it can be managed without danger of starting forest fires.

6. Wood-boring and leaf-eating insects should be killed, if the expense of the process is not too great. It is suggested, for example, that the great damage caused by the spruce-destroying beetle, which kills mature trees by mining the bark of the trunk, may be much lessened. This can be accomplished by cutting and removing most of the infested trees or by girdling trees early in June, to expose them to the attacks of the beetles, then felling and either peeling them or immersing them in water, to destroy the insects before the new crop of beetles emerges from under the bark the following June.[1]

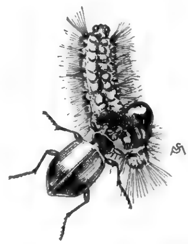

FIG. 100. A carnivorous beetle (*Calosoma sycophanta*) which destroys the caterpillars of the gypsy moth

These beetles have been imported from Europe, and successful colonies of them established in New England. After United States Department of Agriculture

One of the most effectual means of destroying some injurious insects consists in introducing into the region where they abound parasitic or other insects which will kill great numbers of the objectionable species. Plant lice, for instance, are thus killed by ladybugs. Vigorous attempts are now being made to exterminate the gypsy moth in New England by means of parasites and by carnivorous insects (fig. 100) which attack and kill the moth at some stage of its existence. The caterpillars of this moth are extremely destructive to many kinds of trees, which they strip of their leaves in a short time. More than a million dollars has probably been expended in Massachusetts alone in trying to get rid of this pest. The moth was introduced into America in 1869, by a scientist who lived at Medford, near Boston, in the course of some most unfortunate experiments on silk-producing insects.[2]

[1] See "Insect Enemies of the Spruce in the Northeast," *Bulletin 28*, New Series, Division of Entomology, U.S. Dept. Agr., 1901.

[2] "The Gypsy Moth in America," *Bulletin 11*, New Series, Division of Entomology, U.S. Dept. Agr., 1897.

7. Cattle should not be pastured in woods in which it is important to protect the growth of young seedling dicotyledonous trees, but they do not greatly injure mature trees. Sheep pasturing and forestry cannot thrive together, since by browsing the sheep destroy many young seedling trees. On grassy hillsides and mountain sides sheep, by close grazing and by cutting the turf to pieces with their sharp hoofs, soon kill the grassy cover and pave the way for extensive erosion. Great damage has been done in this way in the Rocky Mountain and Pacific Slope regions of our own country. In southern Europe the pasturing of sheep and goats has led to the conversion of great areas of comparatively fertile mountain sides into bare ridges and bowlder-lined torrent beds.

PROBLEMS

1. Irrespective of the hardness, what means are there of distinguishing between coniferous woods and nonconiferous woods?

2. Explain how you can recognize red cedar, cypress, white pine, oak, sycamore, hickory, and black-walnut wood. List the kinds of wood that you know well.

3. What kind of wood is commonly used in your region for the frames of houses? for shingles? for packing cases? for barrels? for fence posts? for railroad ties? for fuel? Explain why each is chosen. What is the most extensive wood-using industry of your locality?

4. What kind of wood is used for lead pencils? for matches? for toothpicks? for rulers? for shoe pegs? Why?

5. Have you become acquainted with any well-grown tracts of self-sown forest? Of what kinds of trees do they mainly consist? How much does the nature of the soil have to do with the constitution of forests that you have seen? Does cultivation affect forest trees?

6. Are coppice woodlands composed of conifers or of hard woods? Why?

7. What rules of forest management are most frequently violated in timber lands that you have seen? Why?

8. What trees are most frequently planted for shade in your vicinity? Give the good and the bad points of each.

9. Get copies of your state forest laws; study and report on them.

CHAPTER IX

FLOWERS

114. The organs of the flower. Although a brief discussion of the parts of the flower was presented in Chapter II, it will be necessary here to consider them more carefully. Many of the most highly organized flowering plants have flowers with four sets of organs, as shown in figure 101. The outer set (the *calyx*) consists of parts called *sepals*, which are usually green and rather leaf-like. Just within or above the calyx comes the *corolla*, which consists of leaf-like parts (*petals*) usually of some other color than green. Next comes a set of *stamens*, which very commonly appear as stalked organs, each with an enlarged, knob-like tip. Finally, the innermost, or uppermost, set of organs consists of *carpels*, which, if united, constitute the compound *pistil*, or, if separate from one another, constitute the simple pistils.

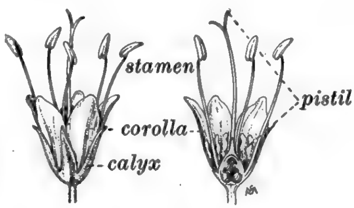

FIG. 101. Flower of *Hydrophyllum*, side view and lengthwise section

A good example of a flower in which the parts of each set except the stamens appear to be more or less joined together. Modified after Decaisne

Not many flowers have organs as distinct — that is, as wholly separate from each other — as they are in the live-forever (fig. 102). In the *Hydrophyllum* (fig. 101) the organs of each set, except the stamens, appear to be more or less united. The pistil seems to be all of one piece, except that it is two-forked at the tip. Hardly any two kinds of flowers have exactly the same forms and arrangements of the floral organs. A few of the forms are figured in Chapter X.

115. What is a flower? A hasty examination of an ordinary flower does not give much evidence as to the relation which its organs bear to the parts of the plant already studied; that is, to the root, the stem, and the leaf. There is, however, plenty of evidence to show that *the flower is a much-shortened and otherwise modified branch, specialized for the production of seed.* The floral organs therefore correspond to leaves. One of the most easily understood evidences of the branch-like character of the flower is the fact that the positions of the flower buds on the branch are similar to those of leaf buds; that is, they are usually either axillary or terminal. Moreover, in its earliest stages a flower bud is developed much as a leaf bud is.

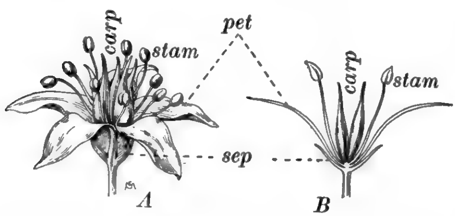

FIG. 102. Flower of live-forever (*Sedum*)

A, entire flower, *B*, lengthwise section; *carp*, carpels; *stam*, stamens; *pet*, petals; *sep*, sepals. An excellent example of a flower in which the parts of each circle are of the same number and all separate. Somewhat enlarged. After Schimper

116. The arrangement of the organs of the flower. The floral organs spring from the *receptacle*, an expanded portion of the flower stalk. Sometimes, as in figure 102, the receptacle is but little enlarged; sometimes, as in figure 103, it is much enlarged; often it is convex or concave. Usually in dicotyledons the floral organs are arranged in *whorls*, or *cycles* (that is, in circular fashion), on the receptacle, but sometimes part or all of them are in spirals. In case there is the same number of parts in each cycle, each part commonly stands opposite a space between two members of the

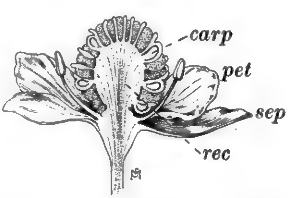

FIG. 103. Lengthwise section of flower of a buttercup

carp, carpels; *pet*, petal; *sep*, sepal; *rec*, large convex receptacle on which the numerous carpels are borne. Somewhat enlarged. After Baillon

adjacent cycles; that is, each petal opposite a space between two sepals, each stamen opposite a space between two petals, and so on. Very often this alternate arrangement of the members of successive whorls is less evident because one or more whorls have more numerous or fewer parts than the others, as in the case of the buttercups and crowfoots (fig. 103), roses, and many other familiar flowers. In many cases, as in the knotgrass (fig. 125), only one set of floral leaves occurs. Such flowers are said to lack petals and are known as *apetalous*. Some flowers, as those of the lizard's-tail (fig. 104) and the willow (fig. 105), are wholly destitute of calyx and corolla.

Fig. 104. Flower of lizard's-tail, with no calyx or corolla

After Engler

117. Staminate flowers and pistillate flowers. Such flowers as are shown in figures 101–104, containing both stamens and pistils, are said to be *bisexual*.[1] Those which contain stamens but not pistils or pistils but not stamens, like those of the willow (fig. 105), are said to be *unisexual*. Many families of dicotyledonous trees and shrubs, such as the Willow family, the Oak family, and others, have unisexual

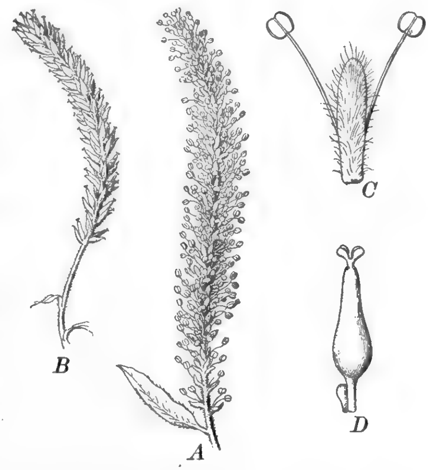

Fig. 105. Diœcious flowers of white willow (*Salix alba*)

A, staminate catkin, natural size; *B*, pistillate catkin, natural size; *C*, staminate flower, magnified; *D*, pistillate flower, magnified. After Cosson and De Saint-Pierre

[1] The flower itself is not sexual at all, as will appear later, but these terms have come into general use, and their application to the two kinds of flower seems likely to continue.

flowers. A flower which has stamens only is said to be *staminate*, and one which has pistils only is said to be *pistillate*.

118. The perianth. In most flowers of dicotyledons the calyx and the corolla are quite unlike in color and texture, as they are, for instance, in roses and pinks. But in many other cases, as in the (monocotyledonous) lilies, there is no sharp distinction in appearance between sepals and petals. This fact makes it convenient to have a single name for calyx and corolla taken together, and the word *perianth* is used to include both sets of organs.

FIG. 106. Bilaterally symmetrical flower of a violet

After H. Müller

When the calyx is composed of separate sepals, and the corolla of separate petals, these parts are said to be *distinct*, and the flower is *chorisepalous* or *choripetalous* (figs. 102 and 103). In the most specialized flowers, both of monocotyledons and of dicotyledons, the calyx, the corolla, or both, appear as if grown together into a cup or tube (figs. 101 and 123). This condition arises from the fact that the floral envelopes did not originate in the form of separate sepals or petals on the surface of the receptacle, but as zones of tissue which developed into a tubular or cup-shaped perianth. In this case the flower is said to be *synsepalous* or *sympetalous*. Sometimes the receptacle itself may be tubular or basin-shaped and bear the perianth on its rim. Generally teeth or lobes of the calyx or corolla show of how many parts it is composed.

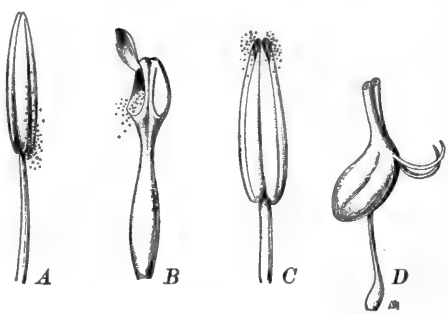

FIG. 107. Various types of anther

A, iris, discharging pollen by a longitudinal slit; *B*, barberry, discharging pollen by uplifted valves; *C*, nightshade, *D*, bilberry, both discharging pollen through holes or pores at the top of the anther. *A*, *B*, *C*, after Baillon; *D*, after Kerner

119. Symmetry of the flower. Except in a comparatively small number of cases (of which the familiar canna, or Indian shot, is a good example) the perianth usually shows some kind of symmetry. Either (as in fig. 102) the parts are arranged in a radial fashion, like the points of a star, or else they have corresponding halves in one plane to the right and left of an axial line, as in pansies and violets (fig. 106), in the most familiar flowers of the Pea family, and in those of the Mint family. Flowers with radial symmetry are said to be *actinomorphic*, and those with corresponding halves are said to have bilateral symmetry, or to be *zygomorphic*.

Sometimes, as in the Milkweed family, the corolla has extraordinary forms which facilitate seed production by the aid of insect visitors (fig. 134).

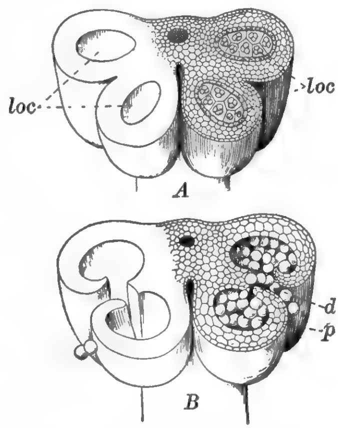

FIG. 108. Diagrams to show structure of an anther

A, younger stage, with four chambers, or *locules* (*loc*), containing pollen mother cells dividing to form pollen grains; *B*, an older stage, in which the pollen grains (*p*) are fully formed and each pair of locules is uniting to form a pollen sac, which will split open and discharge along the line of dehiscence (*d*). After Baillon and Luerssen

120. Parts of the stamen; union of stamens. Many stamens have a form similar to that shown in figure 107, *A*, consisting of a rather slender stalk (the *filament*) which bears a stouter structure, the *anther*. Anthers which have no filaments are said to be *sessile*. Within the anther the stamen produces a powdery or pasty substance known as *pollen*, which, when magnified, is seen to consist of minute grains (fig. 117). These differ greatly in form and markings in different families of plants. The mode of origin of the *pollen sacs* in which pollen is produced is partially shown in figure 108. When the sacs are fully mature, they open and allow their contents to escape.

Stamens are often joined by their filaments so as to form one, two, three (fig. 109), or several groups. In other cases they are joined by their anthers into a single group which surrounds the pistil (fig. 110). In the latter case the pollen is often at length forced out of the anther tube in a single mass by the lengthening pistil (fig. 111).

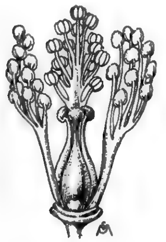

FIG. 109. Flower of St.-John's-wort, with the numerous stamens in three groups

The sepals and petals have been removed. After Warming

121. Carpel and pistil. Although the entire flower is more or less engaged in the work of seed production, it is the *carpel* (from a Greek word meaning "fruit") in which the rudimentary seeds, or *ovules*, originate. In its simplest form, as in the pines and related trees, the carpel consists of a scale of the seed-bearing cone (fig. 224). Each young scale bears at its base an ovule, or rudimentary seed. Among the higher flowering plants the carpel produces the ovules inside a cavity known as the *ovary* (fig. 112).

FIG. 110. Stamens of a thistle, with anthers united into a ring

a, united anthers; *f*, filaments, bearded on the sides. After Baillon

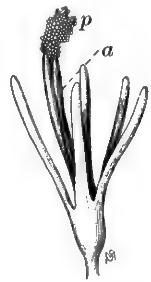

FIG. 111. A single flower of the hundred or more which compose the head of flowers of the Canada thistle

a, the anthers united to form a tube; *p*, the clump of pollen grains forced out from the anther tube by the lengthening of the pistil within the tube. After H. Müller

The carpellary portion of the flower of the higher seed plants (whether it consists of one or more carpels) is known as the *pistil*. Evidently, if the flower has but one carpel (fig. 105), the words *carpel* and *pistil* as applied to such a flower mean the same thing. If there are several carpels, each is one of the units of which the entire pistil is built (fig. 102). A pistil

consisting of a single carpel is said to be *simple*, and one of several carpels, *compound*. The fact that a pistil consisting of several joined carpels is really compound is generally evident from the presence of several chambers, or *locules*, in the ovary (fig. 113, *A*), from the occurrence of several ovule-bearing areas (fig. 113, *B*), or from the forked divisions of the upper part of the pistil (fig. 112). Besides the ovary a pistil often has a stalk known as the *style*, and (in all but the lowest seed plants) there is a pollen-receiving portion called the *stigma*. The relation of these parts is easily understood from an inspection of figure 112.

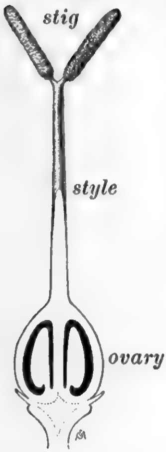

FIG. 112. A pistil with the ovary cut through lengthwise

stig, the stigma

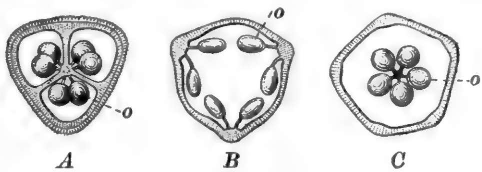

FIG. 113. Three modes of bearing ovules

A, ovary three-loculed, with the ovules, *o*, borne on the axis (*central placenta*) formed by the united partitions; *B*, ovary one-loculed, ovules, *o*, borne on the ovary wall along three *placentas*; *C*, ovary one-loculed, ovules, *o*, borne on a *free central placenta*. After Behrens

Often (fig. 114, *B*) the style is lacking and the stigmas are found on the summit or on the side of the ovary. In this case the stigmas are said to be *sessile*.

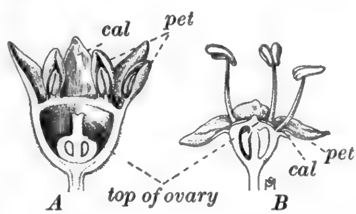

FIG. 114. *A*, perigynous flower of buckthorn; *B*, epigynous flower of English ivy — both lengthwise sections

cal, calyx; *pet*, petals. Note the curious hood-like petals of the buckthorn, each inclosing an anther. *A*, after Berg and Schmidt; *B*, after Wossidlo

122. Relation of the ovary to surrounding organs. In the simplest type of flower having all four kinds of floral organs (fig. 102) the receptacle bears the ovary or ovaries at or near

its apex. The other organs are borne in successive cycles farther and farther away from the tip of the receptacle. But in many of the most highly specialized kinds of flowers the receptacle, as previously stated, bears a sort of tubular or cup-like extension, on the rim of which the petals and the stamens are so borne as to surround the ovary (fig. 114, *A*); or the extension of the receptacle may rise to the top of the ovary, so that the petals (if present) and the stamens appear to grow out of its top surface (fig. 114, *B*). When the ovary stands wholly above the surrounding floral whorls, it is said to be *superior*, or the flower is *hypogynous* (meaning "under the ovary"). When the ovary is encircled by the other floral whorls, it is said to be *half-inferior*, or the flower is *perigynous* ("around the ovary"). When the petals and stamens appear to spring from the top of the ovary, it is said to be *inferior*, or the flower is *epigynous* ("upon the ovary"), as in the evening primrose, (fig. 115).[1]

FIG. 115. Flower cluster of evening primrose

123. Floral diagrams. Lengthwise sections of the flower may be represented by simple diagrams like that of figure 102, *B*. These are convenient to show the relation of the other whorls to the pistil. Cross sections like those of figure 116 show the

[1] The suffix *gynous* refers to the ovary only by a fanciful figure of speech.

relative positions of the members of the different whorls. Such sections do not usually show just what would appear on the cut surface made by slicing the flower across at right angles

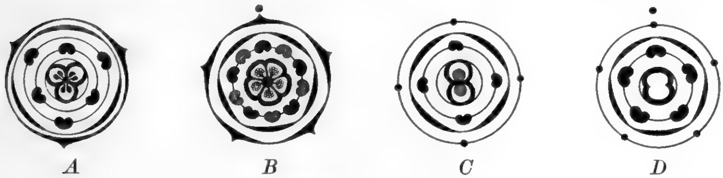

Fig. 116. Floral diagrams

A, Lily family; *B*, Heath family; *C*, Madder family; *D*, Composite family. The dot above the diagram indicates the position of the stem or axis which bears the flowers. The sepals are distinguished from the petals by being represented with midribs. In *B* the alternate stamens are printed lighter, since some flowers of this family have five and some ten stamens. After Sachs

to its axis; they rather give the section that would be obtained by raising or lowering the successive whorls until all stood on the same level, and then making a section. It is usual to distinguish sepals from petals by representing the former with a midrib, and to represent the section as passing through the anthers and ovaries of the stamens and pistils, respectively.

CHAPTER X

POLLINATION AND FERTILIZATION

124. Pollination. In the great majority of flowering plants seed production depends indirectly upon pollen. Of course the pollen grain, in order to act, must be transferred from the anther, where it was formed, to the pistil, in which are the ovules to be affected. This transference of pollen is called *pollination*.

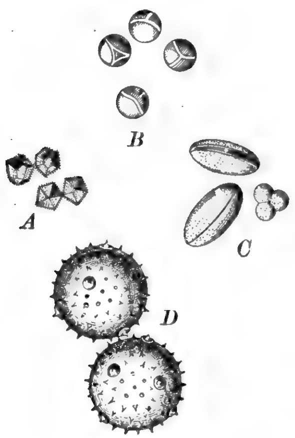

FIG. 117. Types of pollen grains

A, dandelion; *B*, hemp; *C*, gentian; *D*, squash. All greatly magnified. After Kerner

In the higher seed plants the pollen is received on the surface of the stigma, which is usually rough, moist, and sticky, and therefore readily retains the grains which reach its surface. The details of the pollinating process differ so much in different kinds of flowers that even a mere statement of the various types requires considerable space. The significance of pollination will appear more clearly if we first give a very brief account of the results of pollination, and then consider a few of the modes of transference of pollen.

125. Pollen grains; formation of pollen tubes. The form of pollen grain for any given kind of flower, as a lily, a hollyhock, or a cucumber blossom, is quite constant, but those of different kinds are so often unlike that the whole number of forms observed is very great. Usually the grains are separate, like those shown in figure 117, but in many kinds they are united by

extremely slender, sticky threads. The mature grain contains two nuclei, a *generative nucleus* and a *tube nucleus*. Contact of the pollen grain with the moist stigmatic surface brings about osmosis, which results in distention of the pollen grain. At some point the outer coat becomes ruptured and the inner thin coat protrudes through the opening and is the beginning of the *pollen tube*. Then a portion of the contents of the grain passes out into the pollen tube, which is developed from the thin inner coat of the pollen grain (fig. 118, *A*). The pollen tube contains a tube nucleus (t) near its tip and a generative cell (g) somewhere farther back. At length the generative cell divides into two *male nuclei*, these develop into *male cells* (fig. 118, *B*), and the tube nucleus sooner or later disappears.

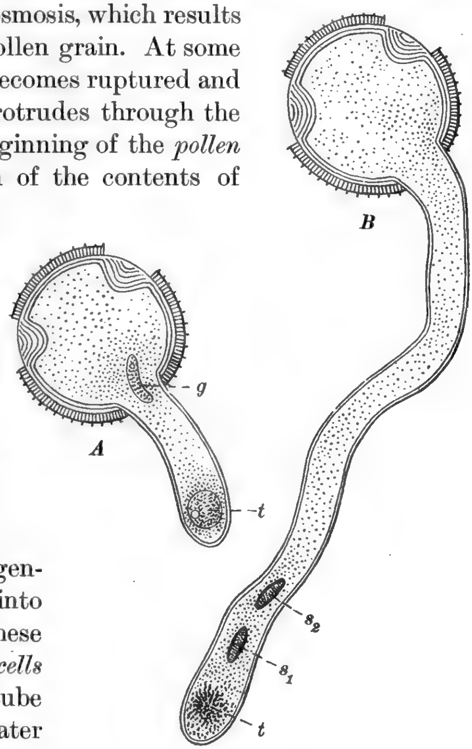

Fig. 118. Germination of the pollen grain of a dicotyledon

A, an early stage in the germination; *B*, later stage, with the tube rather fully developed; g, generative cell; t, tube nucleus; s_1, s_2, male cells formed from the generative cell. It is apparent that when the growth of the tube is far advanced, the tube nucleus (t) almost disappears. Much magnified. After Bonnier and Sablon

126. Course of the pollen tube. The pollen tube readily makes its way between the exterior cells of the stigma and passes onward to the ovary. Sometimes it traverses a tubular passage and sometimes it penetrates the tissues, aided by the corroding action of ferments which it secretes. It is

supposed that the pollen tube is nourished by the cells that are broken down in the path of the tube. The time required for the pollen tube to reach the ovule varies in different plants, ranging from a few hours to more than a year. Usually the tube finds its way into the ovule through a minute opening known as the *micropyle* (fig. 119, *m*), but in some plants it grows directly through the substance of the ovule.

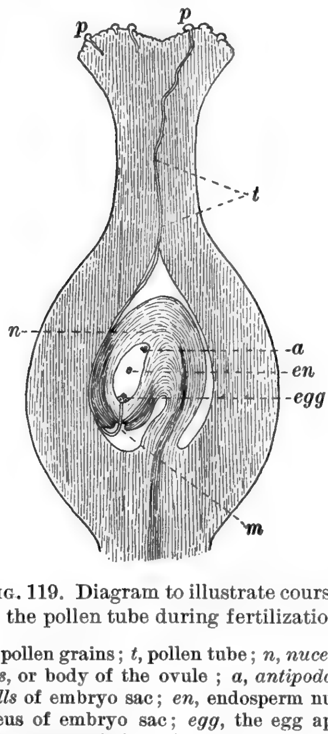

Fig. 119. Diagram to illustrate course of the pollen tube during fertilization

p, pollen grains; *t*, pollen tube; *n*, *nucellus*, or body of the ovule; *a*, *antipodal cells* of embryo sac; *en*, endosperm nucleus of embryo sac; *egg*, the egg apparatus, consisting of the egg cell and two coöperating cells; *m*, the *micropyle*, or small opening, through which, in most ordinary flowering plants, the pollen tube makes its way to the egg at the tip of the embryo sac

127. Fertilization. On entering the ovule, one of the male cells unites with the *egg nucleus* of the embryo sac, which is within the ovule, and the other male cell in some cases, or perhaps usually, unites with the central nucleus of the embryo sac to form the *endosperm nucleus* (fig. 119, *en*). The nature and function of the latter union are not as yet perfectly understood. The fusion of egg nucleus and male cell is, however, a very common and most important phenomenon, occurring in many of the simpler plants as well as in the higher ones. In general it may be said that *fertilization consists in the union of the nucleus of a male cell with the nucleus of an egg cell.* Other illustrations of this will be given in Chapters XV–XVIII. After fertilization the egg rapidly grows into the embryo of a new plant. The ovule also grows

and, together with the embryo, they constitute the seed. Under favorable circumstances the seed may germinate and the embryo grow into an adult plant. One pollen grain may suffice to fertilize an ovule, but the result is more certain if there are several germinating pollen grains for each ovule, though but one male cell unites with one egg.

128. Pollination an ecological subject. Before considering the ecology of flowers it is necessary to explain what is meant by *plant ecology*. It is impossible to study plants in any all-round fashion without paying a good deal of attention to the way in which they are influenced by their surroundings. Any change in the temperature, light, water supply, or supply of raw materials for food-making is sure to affect the plant in some way. Hillside, plain, swamp, lake, or sea — each has its own *flora*, or set of plant inhabitants, which can thrive under the conditions found in their growing place. Plants are also greatly affected by the favorable or unfavorable influences exerted on them by their animal and plant neighbors. *The whole subject of the relation of plants to the environment in which they live is known as plant ecology.* In earlier chapters much has been stated, and still more suggested, that concerns this side of botany, but the subject was not treated in detail, because it is one of the most difficult departments of botanical science and its study is as yet only fairly begun. In this chapter most that is to be said of the processes of pollination should be classed as pertaining to the ecology of flowers.

129. Relation of types of floral structure to pollination. Probably most students of plants, from the earliest times, were somewhat puzzled over the great variety in form, coloration, odor, and other characteristics shown by flowers, but until about a hundred and fifty years ago no botanist seems even to have reasoned about the facts that some flowers are over a yard in diameter, while others are almost microscopic; that some spread the perianth widely and others are narrowly tubular or urn-shaped; that some are sweet-scented, others carrion-scented, and others odorless; that some have extremely

light, dust-like pollen, while others have pollen which coheres in sticky masses — and so on, with a multitude of other differences. These singular facts were first explained in part by two eighteenth-century German botanists, Kölreuter and Sprengel, working independently of each other. Little was afterwards done to clear up the subject until Charles Darwin and a host of other investigators, beginning soon after the middle of the nineteenth century, worked out the details of the methods of pollination.[1]

As a result of these studies it may be said that *flowers owe most of their structural and other characteristics to the fact that these things have enabled them to secure the needed pollination.*

130. Classification according to means of pollination. It is impossible in any brief way to give much of an account of the groups into which flowers are divided with reference to their means of securing pollination. Before outlining these groups it is necessary to define the word *nectar*. This name is given to the sweet liquid found in many flowers — for example, columbine, honeysuckle, and red clover. The nectar is secreted by special organs known as *nectar glands* (figs. 120 and 129) and is often stored at the base of the corolla, sometimes in little pouches, as in the columbines and the honeysuckles.

FIG. 120. Flower of grape, with nectar glands (n) at the base of the ovary

Some of the most important groups of flowers, classified according to their qualifications for securing pollination, are the following:

1. Flowers mostly with inconspicuous perianth, and usually without nectar, destitute of odor, generally with moist or sticky pollen, with knob-like or club-shaped stigmas.

2. Flowers with inconspicuous perianth, destitute of odor, without nectar, with dust-like pollen, with feathery stigmas (fig. 121).

[1] See Knuth-Davis, Handbook of Flower Pollination, Vol. I. Clarendon Press, Oxford.

3. Flowers with conspicuous perianth, often with odor, often with nectar, usually with moist or sticky pollen, with knob-like or club-shaped stigmas.

A good example of 1 is the flower of the peppergrass (*Lepidium*); of 2, the flowers of the grasses; of 3, the showy garden flowers, such as lilies, pinks, and roses.

131. Modes of pollen-carrying. Each of the three groups just described corresponds to a different mode of transference of pollen from anther to stigma.

The flowers of 1 either themselves carry pollen from the stamens to the stigma *of the same flower* (for example, by the curving inward of the stamens as the flower matures) or have it carried from stamens to pistil within the flower by insects which visit the flower, usually in search of pollen. Such flowers are said to be *self-pollinated.*

In the flowers of 2 the pollen is carried, preferably from a flower on one plant to a flower on another plant, by aid of the wind or, in the case of a few aquatic plants, by water. Such flowers are said to be *wind-pollinated* or *water-pollinated.*

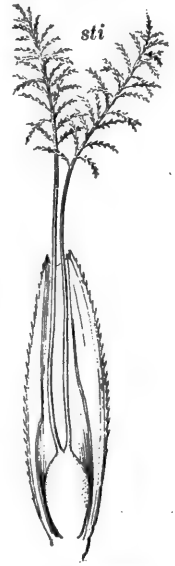

FIG. 121. Pistil of timothy, with feathery stigmas

sti, stigmas. Magnified about 20 times

In the flowers of 3 the pollen is carried, preferably from a flower on one plant to a flower on another plant, usually by insects that visit the flowers in order to secure food.[1] Such flowers are said to be *insect-pollinated.*

132. Self-pollination and cross-pollination. There is a very great physiological difference between self-pollination (1) and cross-pollination (2 and 3). In self-pollination the male cell and the egg nucleus with which it unites originate in the same flower; in cross-pollination they originate in different flowers, preferably from flowers borne on different plants.

[1] Sometimes the pollen is carried by birds, bats, snails, or other animals.

In many kinds of plants self-pollination is entirely effective. In others it produces seed which is good but not so abundant or so sure to grow into vigorous plants as that which is due to cross-pollination. In still other plants cross-pollination is absolutely essential to the production of seeds that will grow at all.

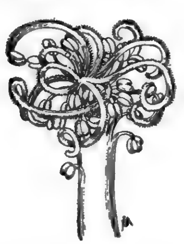

FIG. 122. Stamens and pistils of round-leaved mallow

The flower has been open for a considerable time, and the stigmas have curved so as to touch the anthers and in this way absolutely to insure self-pollination. After H. Müller

To the fact that self-pollination is in many cases not wholly satisfactory, but better than none at all, is probably due the existence of many flowers like the common dooryard mallow, or "cheeses," which has moderately showy petals and is often cross-pollinated by insects, but can also pollinate itself by the contact of the curving stigmas with the stamens (fig. 122). Such flowers are sometimes able to secure insect pollination, but in default of this they do produce a crop of seeds as a result of their self-pollination.

133. When self-pollination is advantageous; *cleistogamous* flowers. Some flowers are usually self-pollinated except when cross-pollinated by accident or human agency. Wheat is a notable instance of the kind, and apparently self-pollination can go on in this grain for a long period without injury to the fertility or the robustness of the offspring.[1] Experiments in raising selected varieties of tobacco seem to show that in this plant

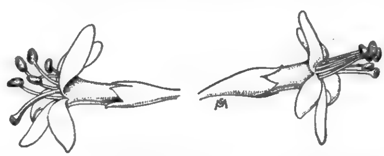

FIG. 123. Facilities for insect-pollination or self-pollination in flowers of the matrimony vine (*Lycium*)

In the flower at the left (earlier stage) the anthers are spread apart and are likely to come in contact with insect visitors; in the flower at the right (later stage) the anthers close together over the stigma, insuring self-pollination. After Knuth

[1] See "Wheat: Varieties, Breeding, Cultivation," *Bulletin 62*, Univ. of Minn. Agr. Exp. Sta., 1899.

self-fertilization, for several generations at any rate, produces better results than cross-fertilization.[1]

Whenever cross-pollination by the wind or by the agency of animals is impossible, it is evident that self-pollination would be advantageous, since it is infinitely better than no pollination at all. Many highly successful weeds owe their predominance partly to the fact that they produce good seed after self-pollination.

Since cross-fertilization at intervals appears to be sufficient to keep up the strength and fertility of many kinds of plants, there might be some advantage in uniting the certainty which characterizes self-pollination with the renewal of strength which comes from cross-pollination. Violets and many other less familiar plants unite the two methods by producing ordinary showy flowers and also inconspicuous closed, or *cleistogamous*, flowers. In violets the latter are borne on flower stalks close to the ground (fig. 124) and usually, before maturing, become partially buried in the earth. Pollination occurs within the closed flower, the pollen tubes developing within the anthers and making their way to the stigma. The cleistogamous flowers produce many more seeds than the showy ones, but the latter insure at least occasional cross-pollination since they are freely visited by bees and other flying insects.

FIG. 124. A violet with cleistogamous flowers as seen in late July or early August, after the conspicuous flowers have disappeared

cl, cleistogamous flowers; *caps*, capsules produced by earlier flowers of the same sort

[1] See "Tobacco Breeding," *Bulletin 96*, Bureau of Plant Industry, U.S. Dept. Agr., 1907.

It is worth while to mention the fact that the characters of the cleistogamous flowers of some violets are so sharply defined that they are of much use in enabling the botanist to distinguish one species from another.

134. Variety of means for pollination. The details of the process by which some kinds of pollination are secured are most complicated. It has taken the studies of many botanists, based often on thousands of observations and carried through a lifetime, to work out our present fairly exact knowledge of most of the methods. Beginners in botany, in a school course, can hardly do more than follow in a very few instances some of the steps of the original investigators of the pollination of flowers. Merely reading about the processes is not enough; the flowers must be watched out of doors, and then their structures carefully examined in the laboratory.

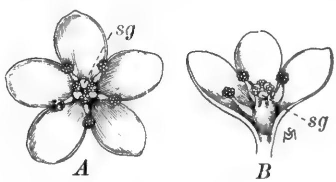

Fig. 125. Self-pollinated flowers of knotgrass (*Polygonum aviculare*)

A, top view; *B*, lengthwise section. Five stamens bend outward and the other three bend inward until their anthers overhang the stigmas *sg*, thus making self-pollination extremely easy. Magnified about 6 diameters. After H. Müller

In the present chapter only about ten floral types will be briefly discussed, out of nearly thirty under which flowers have been classed with reference to their form and mode of securing pollination.[1]

135. Knotgrass[2]; self-pollination. The common dooryard weed known as knotgrass, knotweed, or doorweed is one of the best examples of a plant with flowers suited only for self-pollination. The flowers (fig. 125) are very small (often not as large as the head of a pin), greenish, and borne singly in the axils of the leaves. They are destitute of nectar and without odor, so they do not attract insects. There are usually eight stamens, five outer and three inner ones; these latter, on

[1] See Knuth-Davis, Handbook of Flower Pollination, Vol. I. Clarendon Press, Oxford.

[2] *Polygonum aviculare.*

maturing, close over the stigmas and insure self-pollination. The fact that seeds are abundantly produced shows that the pollination is effective.

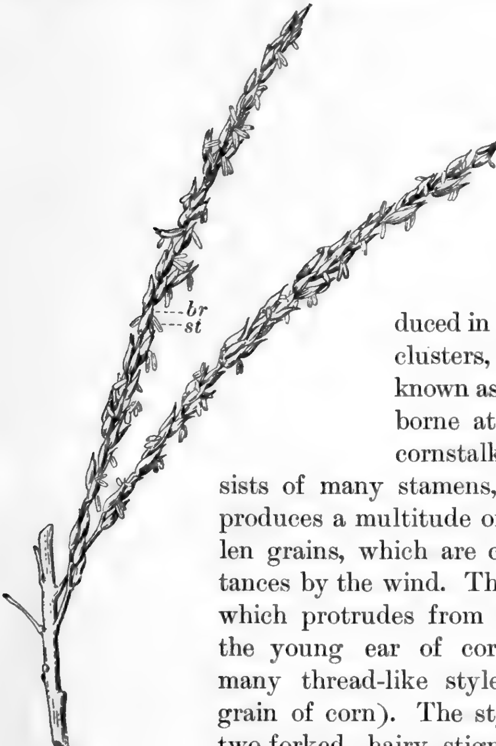

FIG. 126. Part of a corn tassel (staminate flower cluster)

br, a bract; *st*, stamens. One half natural size

136. Corn; pollination by wind. Indian corn affords an admirable example of pollination effected by aid of the wind. The pollen is produced in the staminate flower clusters, which are commonly known as the *tassel* (fig. 126), borne at the summit of the cornstalk. Each cluster consists of many stamens, and every stamen produces a multitude of dry, dust-like pollen grains, which are carried for long distances by the wind. The familiar corn silk, which protrudes from inside the husk of the young ear of corn, is composed of many thread-like styles (one from each grain of corn). The styles terminate in a two-forked, hairy stigma (fig. 127 *C*, *st*). The brush-like character of the protruding stigmas makes them very efficient in catching flying pollen grains.

If the pollen from a corn plant is shaken down upon the stigmas of the same plant, self-pollination only is effected and poor seed results. If the pollen which pollinates an ear comes from another corn plant, cross-pollination is effected and good seed results. Figure 159 shows the difference in growth between plants produced in the next generation from the two kinds of seed.

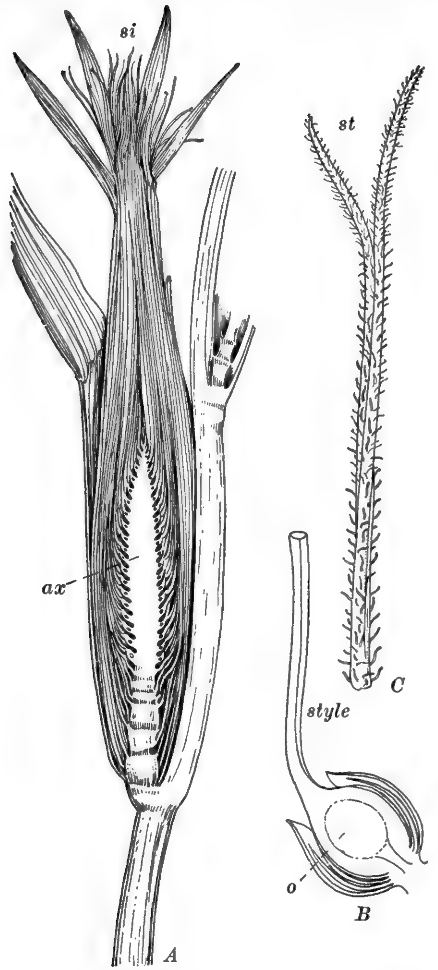

FIG. 127. Structure of an ear of corn (pistillate flower cluster)

A, section of young ear before fertilization of the ovules (grains); *ax*, axis of spike (cob); *si*, ends of silk (styles and stigmas); *B*, magnified section through a grain, showing bracts around the ovary, the ovule (*o*), and the base of the style; *C*, upper portion of style, with the stigmas (*st*) considerably magnified. After F. L. Sargent

137. The potato and the grape; flowers open to all insect visitors. The potato is a familiar example of a flower with wide-open corolla (fig. 128), easily entered by any kind of insect. The flowers, with their white corollas and conical group of yellow anthers, are moderately conspicuous and are visited by insects for the sake of the pollen which they afford. They yield no nectar.

The flowers of the grape are small and greenish. The corolla does not expand but falls off in one piece as soon as the flower is mature. This leaves the stamens and pistil exposed to all kinds of insect visitors. Insects of various kinds are attracted by the sweet odor of the flowers, and find plenty of nectar on the nectar glands which stand almost under the ovary between the bases of the filaments (fig. 120).

138. The periwinkle; a flower with concealed nectar. The common periwinkle,[1] a familiar old-fashioned flower, is an excellent illustration of one way in which nectar is concealed and protected from undesirable insect visitors. The tube of the corolla is moderately long and is partly closed by a sort of disk-shaped enlargement of the style (fig. 129). Part of the under surface of the disk does the work of a stigma.

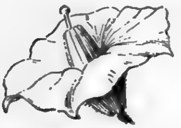

FIG. 128. Flower of potato, with widely expanded corolla

The disk is surrounded by gummy material and bears a crown of hairs at the top. The anthers open inward and so fill the crown of hairs with pollen. The long, slender tongue of an insect visitor (fig. 130), in being thrust through the fringing hairs and down the tube in search of nectar at its base, becomes covered with pollen. In this way some of it will be left on the stigma of the next periwinkle flower visited, which will secure cross-fertilization.

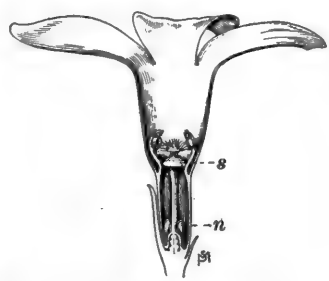

FIG. 129. Lengthwise section of flower of periwinkle (*Vinca minor*), the corolla with a closed throat and with the nectar not accessible to most small insects

s, disk-shaped expansion of the style, stigmatic on its lower surface; *n*, nectar glands at the base of the ovary

Many other instances of concealment of the nectar supply can be discovered by the observing student. One of the most obvious is in such flowers as snapdragon and butter-and-eggs, in which the two-lipped corolla is rather firmly closed, so that it can only be pried open by a moderately strong insect.

There is a large class of flowers in which the nectar is not so much concealed as out of the reach of ordinary insects, since it is at the bottom of a long and narrow corolla tube or in a slender spur of the corolla. Excellent instances of this are found in the flowers

[1] *Vinca minor.*

of the evening primroses, honeysuckles, and Jimson weeds (fig. 131). The nectar from such flowers can best be reached by insects with a very long proboscis, like that of the butterflies or the hawk moths (fig. 131). Many flowers with long corolla tubes are also visited by humming birds.

Red-clover flowers are pollinated mainly by bumblebees. What effect upon the crop of clover seed have field mice, which destroy the nests of bumblebees? How would red clover thrive if introduced into a country where there were no bumblebees?

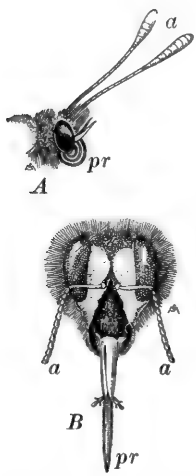

FIG. 130. *A*, head of cabbage butterfly; *B*, head of honeybee

a, antennæ; *pr*, proboscis, or sucking organ. The proboscis of the butterfly is represented as coiled into a spiral. Both somewhat magnified. After Behrens

FIG. 131. Pollination of flower of Jimson weed (*Datura*) by a hawk moth

The nectar is inaccessible to ordinary insects

139. The arum; a pitfall flower cluster. Our common jack-in-the-pulpit is the most familiar American member of the great (mostly tropical) Arum family. The over-arching hood and the tube from which it springs inclose a club-shaped axis on which are borne many inconspicuous flowers. Great

numbers of gnats or midges are attracted to the flower cluster and do not easily find their way out of the chamber in which it is inclosed, but when they do escape, carry pollen with them to the next jack-in-the-pulpit which they visit, and pollinate the flowers there.

The flower cluster of the common European arum[1] has been so much more carefully studied than that of our related American plant, and is so much more successful in detaining pollinating insects, that it is worth while to describe it in some detail. The chamber which surrounds the flower cluster appears to be moderately open, and admits the free entrance and exit of small insects. The *spadix*, or floral axis, bears several rows of downward-pointing bristles (fig. 132, *B*). Small midges are attracted to the interior of the flower chamber by its peculiar ammonia-like smell and by its warmth, which is considerably greater than that of the outside air. The midges readily crawl down through the palisade hairs, often bringing with them pollen with which they have become dusted in other arum-flower clusters. As they crawl down the spadix they pass over the immature staminate flowers (fig. 132, *B*) and

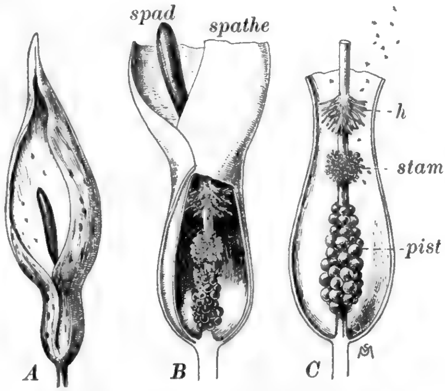

Fig. 132. Pitfall flower clusters of the European arum

A, exterior view of the flower cluster, about one third natural size ; *B*, the same drawn to a larger scale, with part of the covering removed ; *C*, part of *B*, drawn to still larger scale, with the flowers more mature and the hairs (*h*) withering and allowing the escape of imprisoned midges; *spad*, spadix, or floral axis; *spathe*, the hood covering the axis; *h*, hairs closing narrowed part of spathe; *stam*, group of staminate flowers (not mature in *B*, mature in *C*); *pist*, group of pistillate flowers (just matured in *B*, pollinated and developing seeds in *C*). *A* and *B*, after H. Müller

[1] *Arum maculatum.*

then reach the mature pistillate flowers which they pollinate. On attempting to fly out of the flower chamber they find it impossible to get through the fringe of hairs. After a time (often a few days) the stigmas wither, and in place of each a drop of nectar appears, on which the insects feed. At length the staminate flowers mature and allow a considerable quantity of pollen to fall to the bottom of the chamber. The insects crawl about in this, become thoroughly dusted with it, and finally, as the palisade hairs wither and droop, escape and fly away to another blossoming arum plant, and cross-pollinate its flowers in turn. The number of insect visitors to a single flower cluster is enormous, about four thousand midges being found in one flower chamber.

FIG. 133. The common milkweed (*Asclepias syriaca*)
Photograph by Jesse L. Smith

140. The milkweed; a pinch-trap flower. The milkweeds[1] are admirable instances of what are called pinch-trap flowers. There are more than twenty kinds of milkweed in the central and northeastern states, the commonest in many portions of the country being the one shown in figure 133. The flowers, of peculiar form (fig. 134, *A*), are borne in clusters. The general structure of the flower can be understood from figure 134, *A* and *B*. The detail of its structure that is of most interest in the study of modes of pollination is the way in which the pollen is borne. Each of the five anthers produces two rather large pollen masses. Between each pair of anthers is

[1] *Asclepias* and *Acerates*.

found a body shaped somewhat like a grain of wheat (fig. 134, *C* and *D*). This body, the *corpusculum*, is attached at each side to one pollen mass of each of the two adjacent anthers (fig. 134, *B* and *C*). Along the corpusculum runs a slit which gradually narrows toward the upper end and thus acts as a clip, holding firmly any small object that is drawn into it. As the exterior of the flower is smooth and slippery, the only way in which an insect can hold itself in place upon it is by inserting its claws in the slit of a corpusculum. When the insect

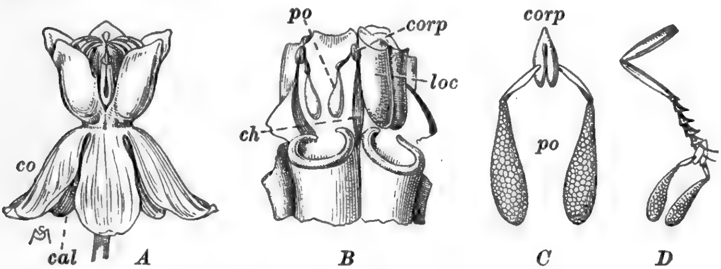

Fig. 134. Flower of the milkweed (*Asclepias*)

A, general view; *B*, side view of flower after removal of the sepals, petals, and nectar-bearing organs; *C*, pollen masses with attached clip; *D*, pollen masses with clip attached to foot of a bee; *cal*, calyx; *co*, corolla; *ch*, stigmatic chamber, inside of which is the stigma; *corp*, *corpusculum*, or body to which the pollen masses are attached, acting as a clip; *loc*, locule, or pollen chamber of anther; *po*, pollen mass. All somewhat enlarged. *A* and *C*, after Prantl; *B*, after Herman Müller; *D*, after Kerner

attempts to fly away, it drags the corpusculum and attached pollen masses with it, suspended by one or more claws (fig. 134, *D*), or sometimes it is held fast and dies. Hairy insects, like bumblebees, often carry away many pollen masses on the hairs of the under surface of the body (fig. 135). If the insect escapes from the flower and visits another, when it thrusts its foot through a corpusculum slit of the second flower the pollen masses already attached to the foot become torn away. The pollen masses thus detached are left in contact with the stigma of the second flower, and in this way most effectively secure cross-pollination.

The strong odor of many kinds of milkweed flowers and the abundance of nectar which they afford bring them many insect visitors. On the flowers of one common milkweed[1] in a single locality one hundred fifteen kinds of insect visitors have been found, including bees, wasps, flies, butterflies, and beetles.

141. Insects as carriers of pollen. Most flowers which require or are benefited by cross-pollination, and which are not wind-pollinated, depend upon insects as pollen carriers. It is not an over-statement to say that, in general, flowers seem to have acquired their odors and their colors (other than green) as means of attracting insects which may serve to cross-pollinate them. Insects vary greatly in their efficiency as pollinators; the small ones with smooth surfaces on the head, legs, and abdomen (such as ants and many beetles) carry little pollen, while bees, moths, and butterflies often carry considerable quantities. As already suggested, insects are led to visit flowers in order to get pollen or nectar. Almost any insect can obtain pollen from flowers of the ordinary type, but the nectar seekers are frequently provided with a very long sucking tube, or proboscis. The honeybee (fig. 130) and the sphinx, or hawk, moth (fig. 131) are good examples of nectar-sucking insects; and the sphinx, with its slender sucking tube, often many inches in length, is especially well equipped for getting nectar from narrow corolla tubes. Cucumbers grown under glass afford a good practical illustration of the importance of insect visits; it is found necessary to keep hives of bees in the cucumber houses in order to insure pollination, fertilization, and consequent crops of cucumbers.

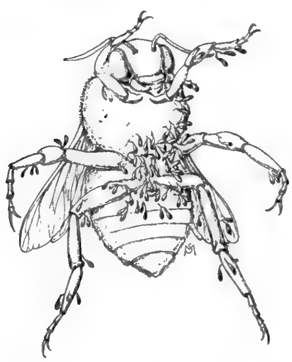

FIG. 135. Under surface of body of a bumblebee, to the hairs of which many pollen masses of green milkweed (*Acerates*) are clinging

After Robertson

[1] *Asclepias verticillata.*

An idea of the number of insect visits made to some flowers may be gathered from the fact that in a single locality one hundred kinds of insects have been seen to frequent dandelion flowers. The statistics in regard to visitors to the flowers of yarrow, Canada thistle, and the willows are fully as remarkable.

142. Odors of flowers as attractions to insects. It is evident from familiar facts that many insects have an acute sense of smell. The way in which flies are attracted by decaying meat or fish, and bees and wasps by a cider press at work or by fruit-preserving operations, is a matter of common observation. A single cluster of carrion-scented flowers has been known to attract carrion flies and dung beetles from a distance of hundreds of yards. Some flowers, such as those of the Virginia creeper (*Psedera*), the Dutchman's-pipe, the blueberries, and many others, are so inconspicuous that apparently their numerous insect visitors must be attracted by an odor which is almost or quite imperceptible to us.

It seems certain that the odors of flowers have been developed with reference to the sense of smell in animals (usually insects), and that these odors serve as a most efficient means of securing insect visits.

It is a most interesting fact that many flowers give off their scent mainly at the time of day when the insects which pollinate them are most active. Thus, some catchflies, the petunias, some kinds of tobacco, and several honeysuckles have little odor by day but are very fragrant at night, when the moths which pollinate them are on the wing. On the other hand, many plants of the Pea family, which are pollinated by day-flying bees and butterflies, give off their scent mostly by day, and especially in strong sunshine.

143. Colors of flowers as attractions to insects. There has been much discussion among botanists as to how far insects are led to visit flowers by displays of color. It appears to be fairly certain that no insects can make out the forms and sizes of objects at a distance of more than six feet, and that many are unable to see clearly even two feet. In spite of this, however,

it seems probable that the colors of flowers are an important means of attraction for many flower-frequenting insects.[1]

The commonest method of color display is that in which the color (other than green) is mainly found in the corolla, as in the flowers of the poppy, rose, sweet pea, and morning-glory. Sometimes the calyx also is bright-colored, or, as in the *Hepatica*, the *Anemone*, and the *Clematis*, the corolla is wanting and the showy calyx looks like a corolla. Not infrequently the display is all made by an enlarged and conspicuous set of specialized leaves (*bracts*) surrounding the flower, as in the flowering dogwood and many euphorbias (fig. 67), or even by highly colored ordinary leaves, like those of the poinsettia.

FIG. 136. Dichogamous flowers of plantain (*Plantago lanceolata*)

A, earlier stage, pistil mature, stamens not yet appearing outside the corolla; *B*, later stage, pistil withered, stamens mature. Six times natural size

144. Prevention of self-pollination; *dichogamy*. Of course, diœcious flowers, like those of the willow, cannot be self-pollinated. In the culture of date palms it is usual to pollinate the pistillate flowers by hand. Monœcious flowers, like those of Indian corn (figs. 126 and 127) are likely to be pollinated with pollen from another plant. As regards bisexual flowers, it is evident that there are many opportunities for self-pollination; but in all cases in which cross-pollination produces more seed or stronger plants, or both, it is clear that anything in the structure or mode of development of the flower which tends to secure cross-pollination is highly advantageous. One

[1] See Kerner-Oliver, Natural History of Plants, Vol. II. Henry Holt and Company, New York. Also Knuth-Davis, Handbook of Flower Pollination, Vol. I.

of the most effectual means of preventing self-pollination in bisexual flowers is the maturing of the stamens at a different time from the pistils; this is known as *dichogamy.* In some flowers, as in the figwort and some plantains (fig. 136), the pistils mature first. In such cases the pollen from older flowers (in the staminate condition) is transferred to the stigmas of recently opened flowers (in the pistillate condition).

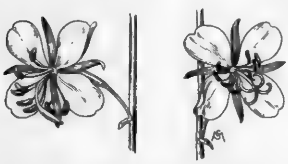

FIG. 137. Dichogamous flowers of fireweed (*Epilobium*)

At the left, earlier stage with stamens mature but the stigmas united into a club-shaped mass. At the right, later stage with stamens withering but the stigmas spread apart and ready for pollination

Usually, as in some mallows and in the gentians and fireweeds (*Epilobium*) (fig. 137), the stamens mature first. An insect visitor to a newly opened flower in the staminate condition becomes somewhat covered with pollen. Then, flying to an older flower in the pistillate condition, the insect is almost sure to leave pollen on the stigmas and thus insure cross-pollination.

It is common to find the stamens of a flower maturing a few at a time, as in "nasturtium," buckwheat, and many other flowers. This gives more opportunities for insects to carry away the pollen than would be possible if it all matured at once.

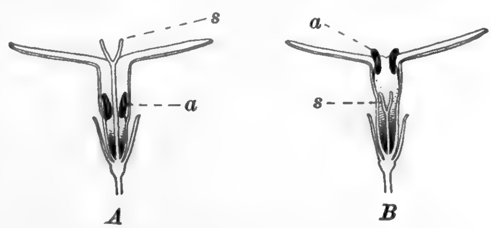

FIG. 138. Lengthwise section of dimorphous flower of bluets

A, long-styled form; *B*, short-styled form; *a*, anthers; *s*, stigmas. About 3 times natural size

145. Prevention of self-pollination; *dimorphism*. A means of preventing self-pollination which is even more effective than dichogamy is found in the structure of flowers in which some have a long pistil and short stamens, others a short pistil and long stamens. This condition

occurs in the flowers of bluets (fig. 138), the partridge berry, the primrose, and some other common flowers. It is easy to see that the tongue of an insect smeared with pollen by contact with the anthers of figure 138, *A* would just come into contact with the stigma of *B*, and that the insect's abdomen covered with pollen in *B* would just touch the stigma of *A*. All the flowers on an individual plant are of one kind (either long-styled or short-styled), and the pollen is of two sorts, each kind sterile on the stigma of any flower of similar form to that from which it came.

On the general subject of pollination of flowers and illustrations of special cases see

DARWIN, The Effects of Cross- and Self-Fertilization in the Vegetable Kingdom. D. Appleton and Company, New York.

DARWIN, Different Forms of Flowers on Plants of the Same Species. D. Appleton and Company, New York.

DARWIN, The Various Contrivances by which Orchids are fertilized by Insects. D. Appleton and Company, New York.

GRAY, Structural Botany. American Book Company, New York.

KERNER-OLIVER, Natural History of Plants, Vol. II. Henry Holt and Company, New York.

KNUTH-DAVIS, Handbook of Flower Pollination. Clarendon Press, Oxford.

WEED, Ten New England Blossoms. Houghton Mifflin Company, Boston.

PROBLEMS [1]

1. Of what use to the plant are flowers? On what grounds would you decide which of two flowers serves this purpose more effectively?

2. In a general way, are the flowers discussed in the earlier or the later sections (sects. 130–145) more perfectly equipped for successful pollination?

3. If the lowest types of flower came earlier than the highest ones, what kind of pollination probably characterized some of the first flowering plants that appeared on the earth?

4. Why does a corn plant growing alone seldom produce good ears?

[1] These problems are to some extent based on the statements in regard to floral structures given in Chapter IX.

5. Some willows, as the common yellow willow (*Salix alba*, var. *vitellina*), are usually represented in this country only by pistillate trees. Can they bear seed? Can they be reproduced?

6. Of the various methods by which self-pollination is rendered difficult, — unisexual flowers borne on the same plant, unisexual flowers borne on different individuals, dichogamy, dimorphism, — which is the least effective? Which is the most effective? Give as many instances as you can of plants which exemplify each method (not citing any of those mentioned in this chapter).

7. Describe as well as you can the qualifications of each of the following flowers for securing pollination: hazel, birch, box elder, buttercup, nasturtium, horse-chestnut, dandelion, locust, sweet pea, primrose.

8. Explain why the subject of pollination is an ecological one. Can you give any reasons why plant ecology is one of the most difficult divisions of the science of botany?

9. Give some practical applications of the principles of pollination to agriculture and horticulture.

CHAPTER XI

FRUITS; SEEDS AND SEEDLINGS; SEED DISTRIBUTION

146. Origin of the fruit. As already suggested (sect. 127), the ovary, after fertilization, enlarges and develops into some kind of seed-containing structure. An apple, a bean pod, and a tomato are good examples of matured ovaries (with or without the addition of other parts) serving to contain the seeds, and each is botanically termed a fruit. Most of the fleshy portion of the apple is derived from the enlarged receptacle and calyx, though a little of it about the core comes from thickening of the walls of the carpels. The papery chambers of the core, with the contained seeds, are the most important portion of the apple for reproduction; that is, for growing new apple trees. A ripe bean pod with its seeds is a dry fruit resulting from the maturing of a one-loculed ovary and its contents; a ripe tomato is a fleshy fruit resulting from the maturing and extensive thickening of a two-to-several-loculed ovary and its contents.

147. Kinds of fruits. The various types of fruits have been carefully classed for purposes of scientific study and description, but in an elementary book it is not worth while to give much space to an account of these classes.[1] The fruits most important for human food are the *grains* — dry fruits with the ovary wall so closely adherent to the seed that the whole is usually taken for a seed. *Nuts*, such as the beechnut, hazelnut, chestnut, and acorn, are hard, dry, one-seeded fruits, most of them larger than grains and resulting from the ripening of a several-loculed ovary only one chamber of which

[1] Some of the principal types of fruits are admirably described in Gray, Structural Botany. American Book Company, New York.

matures. *Berries*, as the botanist understands the term, are generally fleshy fruits resulting from the development of a several-loculed ovary. The grapefruit, lemon, orange, grape, persimmon, and tomato are true berries, though not usually called by that name. On the other hand, a blackberry or a raspberry (fig. 139) is not a genuine berry but a group of fleshy ripened carpels attached to the surface of a large receptacle, and a strawberry is a group of little dry carpels embedded in a large, juicy receptacle. Pomes (apple and pear) have the seeds inclosed by the ripened and fleshy ovary wall, which may itself be inclosed by ripened and fleshy floral structures outside of it. Drupes (peach, apricot, and plum) have the seed inclosed by the ripened ovary, part of which has become hard and part of which is fleshy.

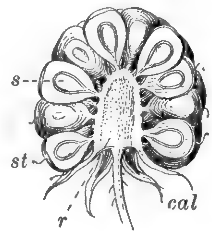

FIG. 139. Lengthwise section through a raspberry

The fruit consists of a cluster of little stone fruits, each of which has much the structure of a plum or a cherry. Every stone fruit is a ripened carpel. *cal*, calyx; *r*, receptacle; *st*, remains of style and stigma; *s*, seed

148. Form and structure of seeds. Something has already been said (sect. 13) of the earliest stages in the formation of seeds. In the present chapter a very brief account of their structure and mode of growth will be given, together with a few words in regard to the ways in which they are dispersed.

A very little observation suffices to show how greatly seeds differ in size and shape. It would not be possible to estimate accurately, without measuring both, how many times larger a lima bean is than a poppy seed; and there are some orchids whose seeds are not a hundredth as large as a poppy seed, while the coconut is vastly larger than any kind of bean. In form seeds vary from nearly spherical ones, like those of mustard and radish, to such thin, flattish seeds as those of milkweed and catalpa.[1]

[1] The student should notice that many objects commonly called seeds, such as those of parsnip, lettuce, and dandelion, are not merely seeds but fruits.

The internal structure of seeds differs greatly in the various kinds. Some contain no separate parts that can be readily made out. Many kinds, however, consist of

1. An *embryo*, or miniature plant.
2. Some plant food stored elsewhere than in the embryo. This is usually called *endosperm*.[1]
3. A seed coat or coats.

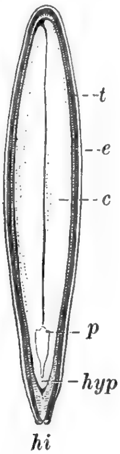

FIG. 140. Lengthwise section of squash seed

hi, hilum, or scar, marking place of attachment to the ovary; *hyp*, hypocotyl; *p*, plumule; *c*, cotyledon; *e* (innermost layer next to cotyledon), endosperm; *t*, testa. Two and one-half times natural size

Frequently the embryo is found to have a fairly well-defined set of organs: the *hypocotyl*, or little stem; the *cotyledons*, or seed leaves; and the *plumule*, or seed bud.

149. Classification according to number of cotyledons. The seeds of one great division of seed plants, the *monocotyledons*, comprising grasses, sedges, palms, lilies, and many other groups, have one cotyledon. As shown in figure 158, *B*, the reserve food is stored mainly outside the embryo.

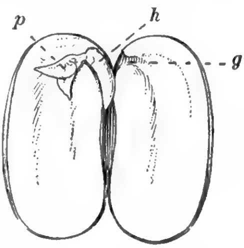

FIG. 141. A common bean split open, after soaking in water

h, hypocotyl, lying on one of the cotyledons; *g*, groove in the other cotyledon, where the hypocotyl lay; *p*, plumule

The seeds of the other and still larger division, the *dicotyledons*, have two cotyledons (figs. 141 and 144). The plant food in the seeds of dicotyledons is often stored in the embryo itself (figs. 140 and 141), as in the chestnut, hazel, beech, oak, pea, bean, squash, and sunflower; or often between or around the cotyledons of the embryo, as in the buckwheat, four-o'clock, castor bean, honey locust, and morning-glory (fig. 144).

[1] Reserve food that was formed outside of the embryo sac is called *perisperm*.

150. Kinds of plant food found in seeds. All seeds contain some protein material, though frequently it is present only in small quantities. Carbohydrates (in the form of starch, sugar, and cellulose) and fats or oils also occur. Many other substances, such, for example, as the poisonous compounds that occur in the seeds of larkspur and Jimson weed, and in the castor bean, the opium poppy, and nux vomica (out of which strychnia is made), are characteristic of certain seeds.

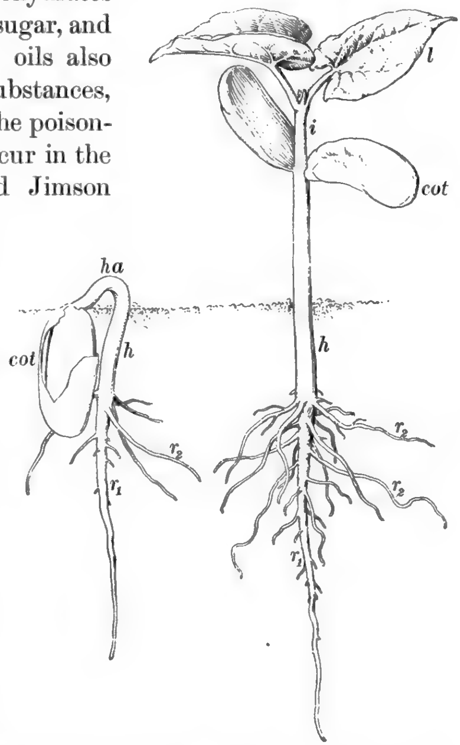

FIG. 142. Two stages in the growth of the bean seedling

In the younger stage the arch of the hypocotyl is but little above the surface; in the older stage the cotyledons have separated, the first internode has elongated considerably, and the first pair of foliage leaves has expanded. *cot*, cotyledon; *h*, hypocotyl; *ha*, hypocotyl arch; *i*, internode; *l*, leaf; r_1, taproot, which proceeded from the tip of the hypocotyl; r_2, branches of r_1. Natural size

The reserve protein is indispensable, since it is the basis of protoplasm, without which life cannot exist nor growth take place. Other reserve foods serve mainly to supply building material for the plant body until it can draw raw materials freely from the soil and the air and carry on photosynthesis for itself. For this purpose the rice grain supplies mainly starch; the Brazil nut, oil; the grain of Indian corn, both starch and oil; and date seeds or coffee seeds, cellulose. Of the substances mentioned proteins,

starch, and oil are highly valuable for human food, and so is sugar, which occurs in small quantities in all the bread grains and in considerable amounts in the best varieties of sweet corn.

The selection and cultivation of plants like the grains, which contain much digest ible food in a concentrated form, and which may retain their food value for some years with little loss, marked a long step upward in the civilization of the human race.

151. The seed coat. The seed coat is more or less efficient in protecting its contents from mechanical injury, such as crushing, and in many cases it protects the more perishable materials within it from decay. Before germination can begin, a certain amount of moisture must usually soak into the seed, either through the general surface, as in most seeds, or, in such hard-shelled seeds as the coconut, hickory nut, walnut, and butternut, through a thin or soft place in the wall. Usually the little opening in the ovule, known as the *micropyle* (fig. 119, *m*), remains in the seed and serves to admit moisture.

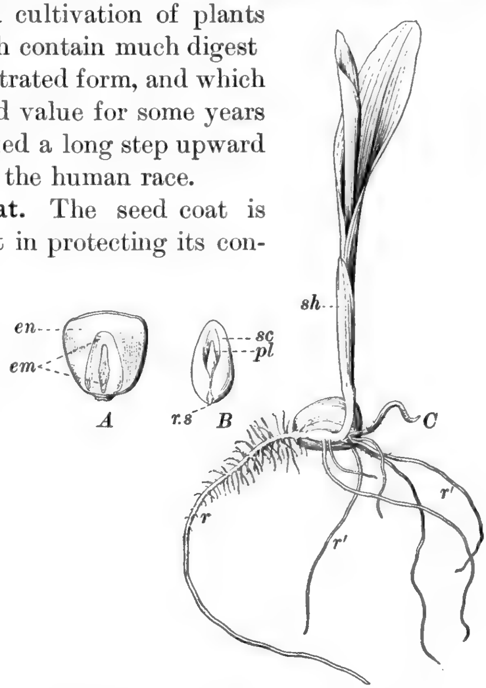

Fig. 143. Grain and seedling of corn

A, lengthwise section of grain; *B*, the embryo removed; *C*, seedling; *en*, endosperm; *em*, embryo; *r.s*, sheath covering tip of rudimentary root; *sc*, scutellum, or absorbing cotyledon; *pl*, plumule; *sh*, sheath-like leaf in which the first foliage leaves are inclosed; *r*, first root, springing from within *r.s*; *r'* later-formed roots arising from other parts of the grain

The coats of many seeds have wings or outgrowths of hairs which aid in their dispersal. Other modifications in the coats

of seeds apparently serve, in some cases, as aids in their dispersal and in others as means of preventing the seed from being eaten by animals.

152. Conditions for germination. A sound, live seed will germinate, or sprout, when suitable conditions are present. The requisites for germination are

1. Proper temperature.
2. Enough moisture.
3. Air or oxygen.[1]
4. Seed coats permeable to air and moisture.

The temperature most favorable to germination varies with the kind of seed; for any given kind there seems to be a lowest limit, a most favorable (*optimum*) temperature, and a highest limit.

Wheat and barley, for example, will sprout at temperatures but little above the freezing point, though they succeed best at about 84° F. Muskmelons and cucumbers sprout at 60° F. but begin much more promptly at temperatures of 93° and upward.

Most farmers have learned by experience that the temperature requirements are not the same for all kinds of seeds. All know, for example, that if corn is planted before the ground is warm enough, it will decay and have to be replanted, but that peas can be sown very soon after the frost is out of the ground.

There is moisture enough in a few kinds of seeds, like those of the willow and the poplar, to allow them to begin to germinate as soon as they are ripe; but most seeds need to be supplied with moisture from without. Too little moisture causes them to germinate very slowly, as is often noticed during spring droughts, while immersing them in water causes many kinds to rot because the air supply is not sufficient.

The germination of seeds planted too deep in clay soils is very likely to be hindered by lack of air. In warm, open soils there is usually air enough; the danger here is that the seeds may dry up because of too shallow planting.

[1] Some seeds begin to germinate without air, but soon die unless it is supplied to them.

153. Rest period before germination. A few kinds of seeds may sprout as soon as they are ripe; most kinds need a period of rest and comparative dryness before they will grow. The

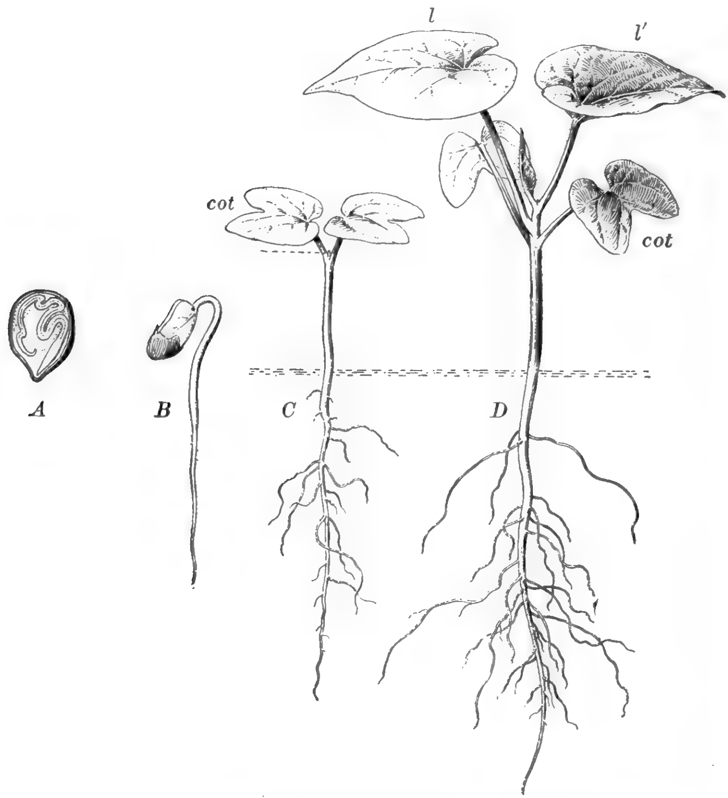

FIG. 144. Seed and seedlings of morning-glory

A, section of seed, showing cotyledons folded together and inclosed in endosperm; *B*, seed germinating, the taproot descending and the cotyledons pushed up out of the ground; *C*, seedling with cotyledons expanded, the plumule showing as a bud at the junction of their leafstalks; *D*, seedling further developed; *cot*, cotyledons; *l*, first ordinary leaf; *l′*, second ordinary leaf

importance of drying seeds is well shown in the case of corn. Kiln-dried corn has, in one instance, been shown to yield sixteen bushels per acre more than air-dried seed of the same variety.

After the rest period the time required for germination varies greatly. Grains, grasses, and many seeds of herbs of the Pea family germinate in from two to eight days, and seeds of most plants of the Parsley family in about fourteen days. The seeds of the hornbeam and ash are said not to grow until the second spring after they are planted.

154. Seed testing. In growing crops from the seed it is desirable to use only seed of the highest quality. The seed should be of one of the best varieties, that is, a choice kind of grain, beet, tomato, or other plant, which is adapted to the soil and climate of the region.[1] Good seed is *pure* and of high *vitality*. Purity means freedom from earth, sticks, broken seeds, bits of leaf, or weed seeds. High vitality means a large percentage of vigorous live seeds which, under good conditions, will grow. The purity can be tested by examining a small average sample of the seed with a good lens and separating the sound seeds of the desired plant from foreign seeds and other impurities. The vitality can be tested by sprouting a convenient number of seeds, one lot from each sample to be examined. Place the counted seeds on moistened blotting paper in a plate and cover them with an inverted plate. If many seeds fail to grow, it is because (1) the seeds have been kept too long and have lost their vitality; (2) the seeds have been exposed to too great heat or moisture, or to too sudden changes in temperature; (3) the seeds were immature or otherwise imperfect when collected. The use of impure seeds or those of low vitality is extravagant, no matter how cheaply they were bought, as impure seeds may introduce many bad weeds, and seeds of low vitality will not give a good stand of the grain or other crop planted.[2]

[1] See Chapter XII.

[2] The teacher can usually secure a bulletin on seed testing from the agricultural experiment station of his state.

See also Lyon and Montgomery, Examining and Grading Grains, Ginn and Company, Boston; Burkett, Stevens, and Hill, Agriculture for Beginners, Ginn and Company, Boston; and Warren, Elements of Agriculture, The Macmillan Company, New York.

155. Types of seedlings. Seedlings[1] may be divided into two groups, *monocotyledonous seedlings* and *dicotyledonous seedlings.* Those of the dicotyledonous group may be further subdivided into plants with *underground cotyledons,* as the pea and the oak, and those with *aboveground cotyledons,* as the maple, bean, squash, and morning-glory (fig. 144).

The monocotyledonous seedling may or may not raise its single cotyledon out of the ground after germination. The onion does so, but the grains do not. In all the larger grains (as in corn) the fitness of the plumule for piercing hard clods or bits of sod is very noticeable and frequently serves the plant well in breaking its way out of the ground.

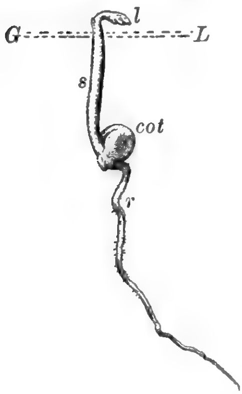

FIG. 145. Pea seedling

cot, the unopened cotyledons; *GL,* ground line; *r,* root; *s,* stem; *l,* rudimentary leaves. One half natural size

Dicotyledonous seedlings with underground cotyledons, like the pea (fig. 145), are better able to force their way out of the ground, if planted deep, than are most of those with aboveground cotyledons, like the bean. Therefore even large seeds of the latter type, like those of the bean, melon, cucumber, and squash, should not be planted deep. Very minute seeds, like those of the portulaca, poppy, and most plants of the Pink family, should be planted on the surface of well-raked, fine earth and then barely covered by sifting over them a little of the finest loam or by dragging a trowel or other suitable implement lightly back and forth over the bed.

156. What becomes of the cotyledons. In the seeds of many monocotyledons, as in the grains and in date seeds, the cotyledon is merely an absorbing organ; it remains within the seed and serves to remove liquefied plant food from the endosperm and transfer it to the growing embryo. In such dicotyledonous seeds as those of the pea, horse-chestnut, and buckeye,

[1] Not considering those of coniferous shrubs and trees.

the cotyledons remain underground, inclosed in the seed coats, and gradually empty their stores of reserve food into the growing seedling. In the bean the cotyledons come out of the ground but never become leaf-like, while in the squash, castor bean, buckwheat, and morning-glory (fig. 144) they emerge from the ground and become short-lived leaves.

157. Reserve food of seeds digested by enzymes. One of the most surprising things about the early growth of seedlings is the rapid way in which many kinds begin to grow even in sawdust or on moist blotting paper. Evidently the plant food must all come from the seed in the beginning, and the removal of most of the reserve food of the seed greatly retards the growth of the seedling (fig. 146). It is not at once clear how the proteins and the starch of some seeds and the oil or cellulose of others are so quickly withdrawn from them and transferred to the growing plantlet. Most of the reserve substances found in seeds are difficultly soluble or quite insoluble in water or the watery sap of plants, but the insoluble substances, before being transferred into the seedling, are transformed into soluble ones. This is due to the action of certain substances known as *enzymes* or *soluble ferments.* An enzyme as found in seeds is a substance secreted

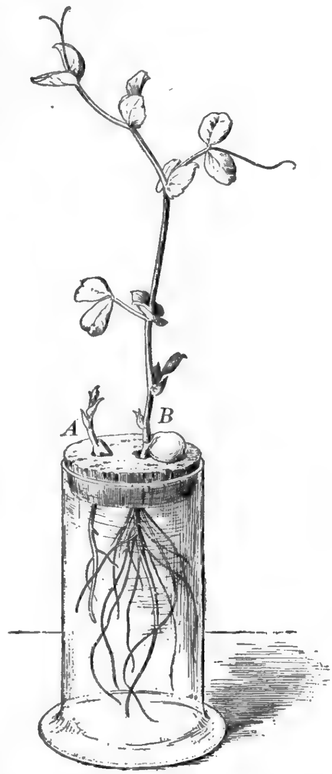

FIG. 146. Pea seedlings growing in water

A, deprived of both cotyledons; *B*, with cotyledons uninjured

by the plant for the purpose of digesting or rendering soluble such plant foods as require digestive action before they can be absorbed by the tissues of the young seedling.

The most familiar case of action of enzymes on a large scale is the malting of barley, in which the starch of the grain is converted into a sugar by diastase. It is said that diastase can change ten thousand times its own bulk of starch into sugar.[1]

158. Propagation due to seeds. Annual plants evidently owe their continued existence to the growth of new crops from the seed. If every grain of Indian corn in the world were to be consumed during some winter, corn plants could not again be grown. Many bulb- and tuber-bearing perennials could continue to propagate their kind for an indefinitely long period without seeds. Some herbs, such as the common field sorrel, and many shrubs and trees, such as rosebushes, black locusts, and silver-leaved poplars, reproduce themselves abundantly by buds formed on the roots, but most trees, and especially nearly all conifers, such as the pines, spruces, and firs, are usually propagated only by seeds.

People in general hardly recognize the wonderful capacity of seeds for carrying on plant life under extremely adverse conditions. Most flowering plants soon die if they are entirely deprived of water for a few days; darkness is fatal to them and very low temperatures kill many kinds of plants in a few minutes; but the seed may be kept for months or years without water, in absolute darkness and at the lowest temperature ever encountered on the earth's surface, and yet remain ready to grow as soon as it is exposed to conditions favorable to germination.

159. Need of seed dispersal. The successive crops of farm and garden annuals are secured by careful seed planting in prepared soil. The seeds of wild plants are also sown, on a still more extensive scale, by natural agencies. In any country the relative numbers of most kinds of wild seed plants

[1] On digestion and enzymes consult J. R. Green, An Introduction to Vegetable Physiology, Chapter XVI. P. Blakiston's Son & Co., Philadelphia.

usually remain from year to year without great changes except those which are brought about by human interference. This fact is evidence enough that seeds in unimaginable numbers must be scattered in such a way as to make good the losses in the plant population of the world due to all destructive causes. The means by which this distribution of the seeds is secured will be taken up in sections 162 and 163.

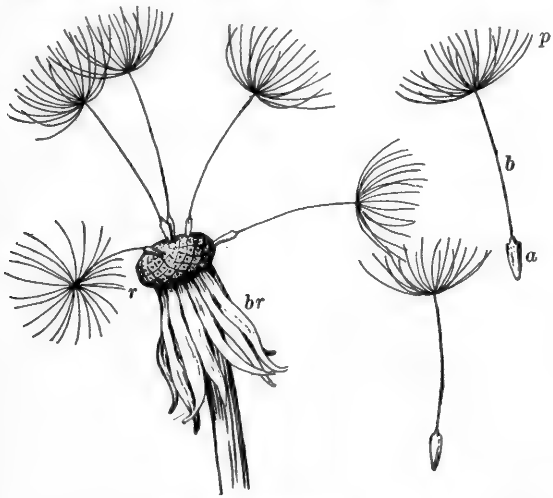

FIG. 147. Dandelion fruits

a, akene; *b*, beak of pappus; *br*, bracts; *p*, pappus (representing the limb of the calyx); *r*, common receptacle for all the fruits. Twice natural size

160. The struggle for existence. Only a small proportion of all the seeds annually produced can have a chance to grow. The resulting contest among plants for a foothold and for the means of subsistence forms one portion of what the great English naturalist, Charles Darwin, called *the struggle for existence.* It is shown by careful calculation that about 5,300,000 acres of land could be sown with the wheat grown at the end of fifteen years from a single parent kernel, if every grain were to grow and live. But the wheat plant does not produce a very large number of seeds. The so-called Russian thistle

(*Salsola Kali*, var. *tenuifolia*), a most troublesome weed, bears from 20,000 to 200,000 seeds. Taking the moderate estimate of 25,000 seeds to a plant, and supposing all of these seeds to grow into plants equally productive, the offspring of the 25,000 individuals would number 625,000,000, and the next generation would number 15,625,000,000,000. Supposing

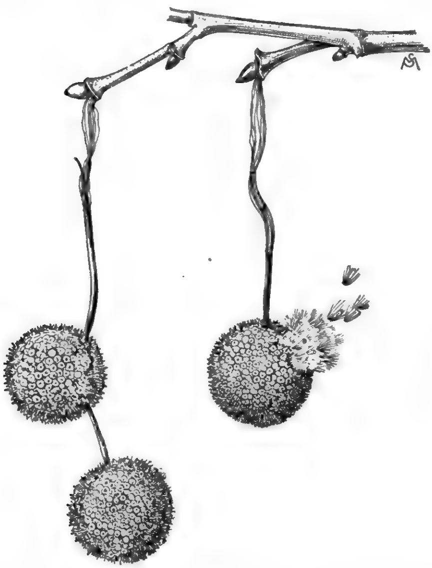

FIG. 148. Globular clusters of fruits of the sycamore in late March

The cluster at the right is broken, and single fruits are being carried off by the wind

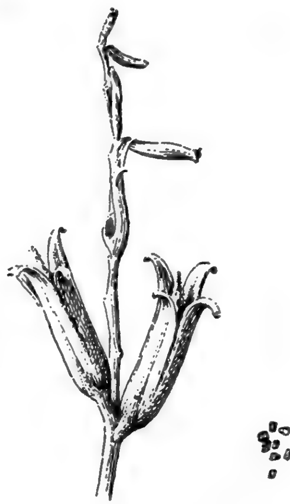

FIG. 149. Pods of evening primrose

The open top allows the seeds to escape gradually. Three fourths natural size

each plant to have a diameter of about 3 feet and to occupy an area of 7 square feet, the student can readily calculate how many square miles of territory the number of plants last named would cover if actually in contact with one another.[1]

[1] To the teacher: If the class will carefully count and estimate the number of seeds produced by some common weeds, and then calculate the number of their possible descendants in the course of five or ten years, the computation will prove most instructive.

Evidently no kind of flowering plant actually increases at any such rate as has just been suggested, or it would soon crowd most others out of existence. The means by which the unlimited multiplication of any one species is prevented are lack of extremely rapid and thorough means of disseminating the seeds, multiplication of the insect and plant enemies of the species (a factor which is often not very important), and over-crowding or competition with other plants of the same or of different species.

161. Competition as a check on increase. No one can realize just what competition among plants means unless he makes some careful out-of-door studies of plants growing under conditions of great overcrowding. A portion of a grainfield too thickly sown, a very weedy bit of garden soil left to itself for the whole growing season, or a piece of recently cleared forest in which coppice growth is starting from old stumps, or where seedling trees are springing up in great numbers — any one of these will teach a most important lesson. The writer has found wild-black-cherry seedlings, to the number of more than 100 to the square foot, beginning to grow in the spring under a large wild-cherry tree. As the parent tree was in thrifty condition and its top was nearly 30 feet in diameter, there might have been some 70,000 seedling cherries every year killed by crowding and shade under this one tree, although, in fact, there were never so many as this.

FIG. 150. Cockleburs

This troublesome weed often grows along a path, where men carry the seeds back and forth in their clothing, and animals in their hair or fur

Competition sometimes results in killing outright most of the competing plants; sometimes it only renders them dwarfish and incapable of producing many flowers or seeds.

The means by which the successful individuals weaken or kill their neighbors are mainly

1. Overshadowing, resulting in deficient photosynthesis in the shaded plants from lack of light.
2. Robbing the defeated plants of water.
3. Robbing them of soluble salts, such as nitrates and phosphates of the soil.

FIG. 151. Fruit of the wild black cherry, a very valuable timber tree

The seeds, which are hard and indigestible, are disseminated mainly by birds. One half natural size

The deprivation of sufficient water and salts interferes with the nutrition of the overcrowded plants and may soon stop their growth.

162. Mechanisms for distributing seeds. Many seeds, such as those of the catalpa, the milkweed, and the willow, have wings or tufts of down which insure their being carried considerable distances by the wind. Tufted fruits, such as those of the thistle and the dandelion (fig. 147), are familiar to most people. Sometimes the plant retains the seeds or fruits for months after they are ripened, and thus secures their gradual dispersal. The globular clusters of fruits of the sycamore (fig. 148) remain on the tree during the entire winter—many of them even till the new crop of leaves has appeared in the spring.

Frequently the pod, or capsule, is so constructed that it opens at the top (fig. 149) and scatters seeds whenever it is swung to and fro by the wind or jostled by a passing animal.

Fruits, clusters of fruits, and plants full of fruits are rolled along the ground (especially over the snow) by the wind, often for great distances, scattering seeds as they go. If it is a whole plant that travels, or a large part of a plant, it is known as a tumbleweed. Such are the Russian thistle (*Salsola*), tumble-mustard (*Sisymbrium*), winged pigweed (*Cycloloma*), ghost-plant (*Amaranthus*), and the fruit cluster of old-witch grass (*Panicum*); the white-pine cone is an example of a single fruit traveling in the same way.

Many aquatic plants, as grasses, rushes, sedges, water dock, lotus, bur reed, and a multitude of other species, have fruits or seeds which float, often for long distances, and then lodge and grow.

Burs of many kinds (fig. 150) lodge in the hair, fur, or feathers of passing animals and are finally dislodged in various distant places where they may grow.

Fig. 152. Red raspberry bush in fork of a maple

163. Dispersal of edible seeds. Edible seeds and fruits (such as nuts, the grains, and berries) and stone fruits (like plums and cherries) are frequently swallowed by animals and later voided undigested and in a condition to grow. In this way wild cherries (fig. 151) and wild apples are planted about pastures and in open woods. Also, raspberry, currant, and gooseberry bushes, asparagus, and bittersweet may be found growing in the forks of trees (fig. 152). Squirrels, blue jays, and some other animals carry away nuts and bury them, often leaving them to grow the following spring.[1]

[1] On the general subject of seed dispersal see Kerner-Oliver, Natural History of Plants, pp. 833–877, Henry Holt and Company, New York; also Beal, Seed Dispersal, Ginn and Company, Boston.

PROBLEMS

1. Show how widely the botanist's use of the term *fruit* differs from that of people who are not botanists. Make out a list of some common articles of food that are properly classed as fruits though not sold under that name.

2. Show that many young seedlings live on the same kind of vegetable food that human beings eat. Is this true of a very young date palm?

3. How would you perform a series of experiments to discover the optimum temperature for germination of the seeds of agricultural plants? What precautions would you need to take?

4. If the prices of very low-grade red-clover seed and of high-grade seed are respectively $5.20 and $15.00 per bushel, but only 18 per cent of the poor seed germinates, while 96 per cent of the good seed germinates, which is more expensive to use? If the poorer seed contained 26 per cent of weed seeds and the better quality was practically pure, how would this affect the question as to which kind is more economical? Get some clover seed and test it to see what percentage of it will grow.

5. State some reasons why better results are obtained by sowing large, plump seeds of any kind of grain or other annual plant than by using small, shrunken seeds.

6. A pound of red-clover seed contains about 300,000 seeds. Frequently 15 pounds to the acre (43,560 sq. ft.) are sown. How many plants to the square foot might such a sowing produce? Does this number seem too large or too small properly to cover the ground? Is it, then, a waste of seed to sow 15 pounds per acre? Explain.

7. How long would most useful plants of the farm and garden maintain themselves if left to grow unaided among their wild competitors? What instances of this have you ever seen?

8. What are some of the plants which first spring up where a piece of woodland has been cleared and the clearing burned over? Explain why these plants are among the first to establish themselves in such places.

9. Why are uncommon kinds of plants often found near wool-cleansing establishments?

CHAPTER XII

PLANT BREEDING

164. The basis of plant breeding. It is the business of the professional plant breeder to discover or originate desirable varieties of plants and then to perpetuate them. As soon as he becomes certain that he has obtained a really valuable new variety, he proceeds to multiply it until he can offer to growers everywhere its seeds, bulbs, or other means of reproducing it.

The possibility of producing new varieties rests largely upon two highly important facts:

1. *That all the higher plants vary from generation to generation.*

2. *That the higher plants sometimes mutate.*

Variations are familiar enough to every observing person. No two corn plants, bean plants, or tomato plants are just alike, even though they may have been grown from seed from the same ear, the same bean pod, or the same tomato. The variations may be noticed in the root, stem, leaf, flower, or fruit, or in several or all of these. The term *mutation* is less commonly used than the term *variation.* It is the scientific name for the kind of abrupt appearances of forms, extremely unlike the parent, long known to horticulturists as *sports.* A single bud upon a peach tree may mutate and produce a branch which will bear nectarines, and a bud upon a tree which bore purple plums has been observed to grow into a branch which bore only yellow plums of a kind previously unknown. Some of the most valuable varieties of the grains are seed sports, or mutations first noticed in the seedling grown from the seed of a very different variety.

165. Unit characters.[1] Much more definiteness has recently been given to the discussion of questions relating to plant breeding by the introduction of the idea of *unit characters*. Every species or variety of animal or plant is considered by many authorities to be composed of a set of unit characters, or simple features by which it is distinguished from other species or varieties. Just what this statement means will appear more clearly if some of the unit characters which belong to different varieties of a familiar species of plant are set down. In the case of timothy, our most important grass for haymaking, twenty-eight opposing character pairs have been noted. Some of these are

Heads
- Long or short
- Continuous or interrupted
- Large-seeded or small-seeded
- (and 8 others)

Leaves
- Long or short
- (and 4 others)

Stems
- Tall or short
- Many or few branches from the base of the stem
- (and 4 others)

Nodes
- Near together or widely separated
- (and 2 others)

Habit characters
- Inclined to blow down or remaining erect
- Rusting readily or rust-resistant
- Early or late maturing

Careful breeding would probably soon give a variety with any one of these twenty-eight characters strongly marked, and several of them could be combined in a single variety if desired.

[1] See the valuable summary of this subject, given by Professor Herbert J. Webber in his address before the American Breeders' Association, *Science*, April 19, 1912.

166. Selection of desired characters. Of course the practical plant breeder would concern himself only with the characters of timothy which affect its value for haymaking or for a pasture grass. For haymaking he would try to get a combination of characters which would give abundant leaves, stems branching freely from the base, and heads and seeds large enough to insure good reproduction. A single plant of a good type will yield about five times as much hay as one of a poor type like that which is shown in the upper part of figure 153.

Fig. 153. Variation in timothy

The two lower plants are of the same age and from the same seed, growing side by side in the field. The one at the left is a dwarf; the one at the right a large and desirable type. The one in the upper part of the figure is a dwarf plant with very large heads — an undesirable type, from its scanty leafage and few stems. Photograph by New York Agricultural Experiment Station

To do successful work in plant breeding, one of the first requisites is trained observation — ability to recognize the appearance of any valuable character or group of characters in growing plants. A skilled botanist once found twenty-three kinds of wheat growing in a field where the grain was supposed to be all alike. One of these kinds was isolated and became the parent of an excellent variety that has been extensively cultivated for about a century. The Concord grape sprang from a seedling of one of the common wild grapes of New England. Its originator failed to get another important new variety from among 22,000 seedlings that grew from Concord seeds. One of the most valuable blackberries of the low-growing (dewberry) type, the Lucretia, is a variety found growing wild upon a West Virginia plantation during the Civil War. The well-known Wealthy apple originated as a seedling discovered after ten years of seed planting and the use of much more than a bushel of apple seeds.

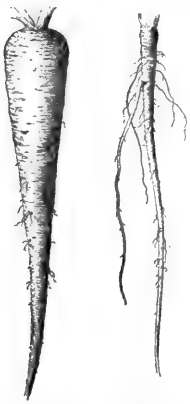

FIG. 154. Effect of cultivation on the parsnip

The parsnip at the left is a cultivated one; that at the right, a wild one at the end of the first season's growth. One eighth natural size

167. The perpetuation of desirable varieties. In the case of shrubs or trees which can readily be grafted or budded (sect. 87), or in plants like the potato, the canna, or the gladiolus, which can be propagated by tubers and bulbs, it is easy to perpetuate any new variety. If it is necessary to reproduce the plant by means of seed, it may be found that the desired variety always "comes true"; that is, reproduces itself with little or no perceptible change, as is the case with the established varieties of the grains (sect. 171). On the other hand, the plants may tend to "run out"; that is, to revert to the average original type from which the selected variations have been developed. Sugar beets are particularly troublesome

in this respect, so that it is sometimes necessary to select only about one best beet out of every thousand to grow seed for the next crop.

In the case of plants grown for the production of seed of standard varieties for the market, as beans, peas, or any of the many flowers (such as sweet peas), in regard to which there is much competition, great attention is paid to weeding out and destroying plants that do not conform to the standard. This process is called *roguing*. The maintenance of the breed depends largely upon the intelligence and thoroughness with which it is carried out.

168. Ancient and modern plant breeding. No one knows when plant breeding began, because the earliest attempts of man to cultivate useful plants date back to unknown antiquity, and it is highly probable that the first growers of plants for human food more or less unconsciously selected the best seeds to be sown for a new crop, and were thus really practicing plant breeding. Among the Chinese, agriculture began at least 4600 years ago, and for a considerable part of that time they have paid much attention to the perpetuation of desirable varieties of the plants of the farm and garden.

Modern plant breeding did not begin at any definite date. Some valuable work was done in selecting and propagating improved varieties of wheat in Great Britain as early as the first quarter of the nineteenth century, but it was not until toward the middle of the century that many investigators began to try to put plant breeding on a scientific foundation, working with plants ranging all the way from the cereals to sugar beets. One of the main problems in plant breeding is that of predicting the way in which the characters of a plant will be inherited by its descendants. In a large number of cases, a number which is rapidly increasing, it is possible to make such predictions with scientific accuracy. These are based on the immense mass of data which has been gained from tens of thousands of experiments made by scientific investigators and by practical plant breeders everywhere.

The best way in which to illustrate what modern plant breeding means is to give a few instances of the methods actually employed.

169. Wheat breeding: its purpose. Wheat is the most important grain for human food in temperate climates, and North America is by far the greatest wheat-producing region in the world. The annual value of the crop of the United States ranges from $250,000,000 to $500,000,000. Scientific wheat breeding began barely a century ago, and has progressed more in the United States since 1890 than during all our previous history.

Some desirable qualities to be sought in wheat breeding are (1) large yield per acre; (2) good quality for bread-making, requiring a high per cent of the tenacious *gluten*, the main protein portion of the grain; (3) hardiness, shown in winter wheat, in resisting severe winter conditions; (4) resistance to rust; (5) resistance to drought.

Not all of these qualities can be combined in the highest degree in any one variety, and therefore every region should grow the particular kind of wheat best suited to the local conditions and market. About eight species of wheat are recognized, and the number of varieties of these species is very large.

170. Wheat breeding: the method. In order to show how carefully the process of wheat breeding is managed in our best agricultural experiment stations, the principal steps of the operation are here given in the barest outline, omitting many most important details.[1]

1. Ten thousand large, sound kernels of a single good variety of wheat are selected and planted in hills, and each hill is numbered. About 95 per cent of the poorer plants are rejected as they mature. When mature, the heads of each of the chosen plants are put together in an envelope and preserved.

[1] See *Bulletin 62*, University of Minnesota Agricultural Experiment Station, and *Bulletin 29*, Division of Vegetable Physiology and Pathology, U.S. Dept. Agr.

When thoroughly dry, the product of each plant is weighed, and only a few of the heaviest groups of heads are kept for seed.

2. The second year about a hundred of the seeds of each mother plant are planted in a group (hundred-group or *centgener*). To each such group is given a special designating number. Heads of several of the best plants in each hundred-group are reserved for seed. The total produced by each hundred-group is weighed. This enables the experimenter to estimate the comparative value of the mother plants.

3. The third year the process of the second year is repeated.

4. The fourth year the same process is repeated.

5. The fifth year the most promising varieties are planted in small fields in the ordinary way. Those varieties which yield abundantly in the field and turn out well in the milling tests which are applied to the harvested grain, are distributed among farmers for seed wheat.

A new variety can soon be introduced over an immense territory. It is estimated that in fifteen years from the time of planting one seed its descendants might be made to cover more than 5,000,000 acres of wheat fields.

Wheat breeding is still making such rapid progress that at present it is not possible to say how much the quality and quantity of our wheat crop may yet be improved by the introduction of better varieties. The total number of acres in the United States differs considerably from year to year. It seems likely, as a rule, to exceed 45,000,000.[1] The average yield ranges between 10 and 15 bushels per acre, although it is possible, with the most improved seed on the best soils, to raise more than 40 bushels per acre.[2] Choice of the best seed would undoubtedly increase the average yield 5 or more bushels per acre. It is easy to see how important a gain this would be if it were calculated in terms of the current price of wheat.

[1] See Carleton, "The Future Wheat Supply of the United States," *Science*, August 5, 1910.

[2] See Hopkins, Soil Fertility and Permanent Agriculture. Ginn and Company, Boston.

171. Principles upon which wheat breeding depends.[1] The work of the earliest breeders of wheat was not based on any general knowledge of the laws of plant variation and inheritance. The principles of breeding, as applied to the small grains, were first worked out by Professor W. M. Hays of the University of Minnesota Agricultural Experiment Station, and by Dr. Hjalmar Nilsson, director of the experiment station at Svalöf, Sweden. Some of the main principles upon which wheat breeding depends may be stated as follows:

Fig. 155. A hybrid wheat and the parent forms

The hybrid is in the middle. It is somewhat intermediate between the parents, being nearly (though not quite) beardless, like the right-hand parent, with a length of head intermediate between the two and with the grains and their covering bracts stout, as in the left-hand parent. Photograph by Minnesota Agricultural Experiment Station

1. Every species of cereal usually comprises many well-marked varieties, or, as they are sometimes called, *elementary species*. Sometimes several hundreds of these are included in each of the longest-cultivated species of grain; this is notably true in the case of wheat.

2. The varieties, while still growing in the field, may be distinguished by such botanical characters as the position, shape, size, and bearded or beardless condition of the head; the form, size, and appendages of the spikelets which it contains; and the size, shape, color, and hardness of the grain.[2]

[1] See De Vries, Plant Breeding. The Open Court Publishing Company, Chicago.

[2] The hardness cannot be accurately known until the grain is ripe and dry.

3. The varieties distinguished by such characters as are mentioned in the preceding paragraph often differ much in their economic value, which depends on such qualities as productiveness, resistance to drought, resistance to rust, and the grade of flour which they produce.

4. Varieties usually come true from the seed, so that, when one has been chosen and isolated, it may be grown indefinitely with little change.

172. Variation in corn. Indian corn is preëminently an American plant. At the time of the discovery of America,

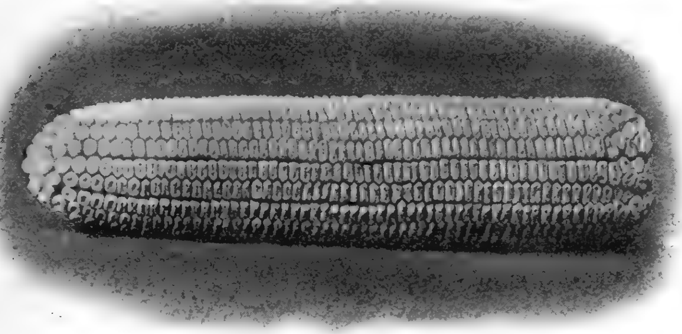

FIG. 156. A prize ear of Johnson County White corn[1]
An admirable type of dent corn. Photograph by L. B. Clore

and probably for a long period before that time, it was grown by the Peruvians, by the Mexicans, and by many tribes of Indians. It is supposed to have originated in South America or Central America, near the west coast. Varieties of corn differ greatly in size (from $1\frac{1}{2}$ to 22 feet high) and in the time required for maturing. Some corn in Paraguay is said to ripen in one month, while Illinois field corn requires from four to five months.[2]

[1] This ear of corn was bid in by the grower (Mr. Clore) at an auction sale of exhibits at the Chicago National Corn Exposition in October, 1907. The price paid was $250.

[2] See *Bulletin 57*, Office of Experiment Stations, U.S. Dept. Agr., 1899.

Six well-defined types of corn are recognized, but only four are of much economic importance. These are *pop corn*, with small kernels and with endosperm all or nearly all horn-like; *flint corn*, with much horn-like endosperm and a grain too hard to be fed to most animals without being ground; *dent corn*, with the kernels indented at the outer end; and *sweet corn*, in which most of the starch of the endosperm is replaced by a kind of sugar. Of these four kinds dent corn is by far the most important, constituting the great bulk of the crop in the corn belt. Each of the types of corn has many varieties; of dent corn alone more than three hundred have been named and described. Most of these varieties are found to show slight variations, which make them more or less desirable for the corn grower, and his efforts must be directed mainly toward improving the quality of existing kinds.

173. Qualities sought by the corn breeder.[1] Of the many qualities that may be sought by the corn grower four of the most important are (1) productiveness; (2) high percentage of proteins; (3) high percentage of oil; (4) low percentage of oil.

With reference to (1) it suffices here to say that the average yield of corn for the entire United States, according to statistics for 1908, was a little over 26 bushels per acre; for the New England States, with soil no better than the average, and with a poorer climate, it was 40.5 bushels; and for some New England growers it was 100 or more bushels per acre. No small part of the difference between the average 26-bushel yield and the 100-bushel yield depends on the choice of seed, though cultivation and soil are also important factors.[2]

[1] See *Bulletins 55, 82, and 87*, Illinois Agricultural Experiment Station.

[2] See *Massachusetts Crop Report*, May, 1910.

Throughout the Southern states and elsewhere boys' corn clubs are coming to be extensively organized. The object of these clubs is to grow more and better corn by choice of the best seed and by thorough cultivation. In the State Corn Club Show held at Atlanta, Georgia, in December, 1912, there were exhibits made by 70 boys who had each grown 100 or more bushels of corn to the acre. The state record for a boy's crop (raised at a profit) is held by Ben Leath, of Kensington, Georgia, who in 1911 grew 214 bushels and 40 pounds of corn on one acre, at a net profit of $182.60. See *Bulletin 175*, University of Georgia.

Greatly increased care in its selection would probably at once add more than $100,000,000 to the annual value of our corn crop. The structure of the grain of corn, as shown by the diagrams in figures 157 and 158, is such that the relative amounts of proteins, starch, and oil can be roughly estimated by a mechanical examination of the grain. This most important fact was discovered by Professor C. G. Hopkins, of the University of Illinois. The proteins are very largely stored in the horn-like part of the endosperm (fig. 157, *p*), and in the embryo; the starch is mainly found in the white, floury part of the endosperm (*s*); and the oil is nearly all in the embryo (*e*). If seed corn is chosen from ears with kernels in which the horn-like portion is highly developed, the result will be a crop with a large percentage of proteins; seed corn with large embryos will yield a crop rich in oil, and seed corn with small embryos a crop poor in oil.

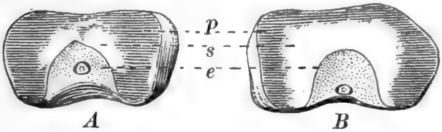

FIG. 157. Kernels of corn with high and with low percentage of proteins

A, high proteins, *B*, low proteins; *p*, horny layer, consisting largely of proteins; *s*, white starchy portion; *e*, embryo. After *Bulletin 87*, University of Illinois Agricultural Experiment Station

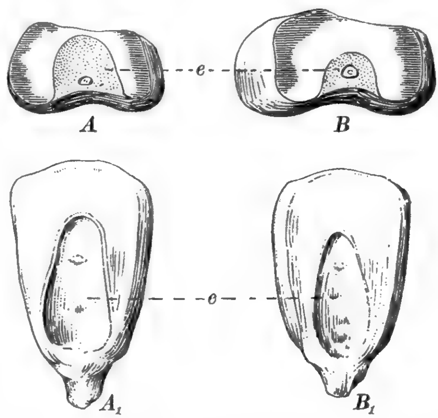

FIG. 158. Kernels of corn with high and with low percentage of oil

A,A_1, cross section and face view of high-oil kernels; B,B_1, cross section and face view of low-oil kernels; *e*, embryo. Most of the oil (as well as a good deal of the proteins) is contained in the embryo, so that an embryo large in proportion to the size of the kernel means a high percentage of oil in the grain. After *Bulletin 87*, University of Illinois Agricultural Experiment Station

Corn with high proteins is especially valuable as a food for man and the lower animals, since the most serious fault found with corn as a cereal food is its low percentage of proteins compared with its oil and carbohydrates. Corn with high oil value is especially desired by the glucose manufacturers, since they also manufacture corn oil, which is the highest-priced component of the grain. Corn with a low percentage of oil is in demand for feeding hogs for bacon, especially for exportation. It has been found possible, at the University of Illinois Agricultural Experiment Station, to breed low-protein corn with an average percentage of 6.7 proteins, and high-protein corn with an average percentage of 14.4 proteins. At the same station the average low-oil corn contained 2.5 per cent of oil, and the high-oil corn 7.0 per cent. The process of selection must be kept up, for the variations thus obtained are not permanent varieties.

174. Method of corn breeding. In a general way it may be said that the method of breeding corn is based on the same principles as those adopted for wheat and other cereals. There are, however, many variations in details, some of the most important depending on the fact that the plants should be pollinated with pollen from other individuals, but that these should, so far as possible, be all of the same stock. It is not sufficient that all should be of the same variety; the most rapid progress will be attained if all the parent plants are descended from the same ear of corn.

It will not be necessary to give in detail all the methods followed in the selection of seed and the precautions taken to prevent mixture of varieties in the growing crop. Successful corn breeding demands

1. The choice of the most desirable known variety as a basis for breeding for any given purpose.

2. The selection *in the field* of well-matured ears from the best plants.

3. Growing trial rows the next season from the ears mentioned in paragraph 2, each ear planted in a row by itself.

Every other row should be detasseled, to prevent the plants from pollinating their own ears, and seed ears should be saved only from the detasseled rows.

4. The continuation, during subsequent seasons, of the process of seed growing from the best plants obtained by the process of paragraph 3.

In beginning to breed corn it is better to use seed obtained from the locality in which the experiment is to be made; that

FIG. 159. Cross-pollination and self-pollination

The effect of cross-pollination and of self-pollination on the growth of corn from the seed. The two rows of small plants at the left grew from seed produced by self-pollination, the larger plants of the other rows from seed produced by cross-pollination. Photograph furnished by Funk Bros. Seed Co.

grown under decidedly different conditions may not succeed. If high-oil or low-oil corn, or high-protein or low-protein corn, is desired, the ears used for seed must be carefully chosen with reference to the development of the horn-like endosperm or of the embryo (figs. 157 and 158). Selection in the field, as mentioned in paragraph 2, is necessary in order to make sure that the ears chosen grew on vigorous plants and that ears from the same plant are kept together. If detasseling is

not thoroughly carried out, much self-pollination and self-fertilization is sure to occur. Corn which is self-fertilized produces smaller and less vigorous plants the next season than cross-fertilized corn (fig. 159). Detasseling has therefore been found to increase the yield of corn more than ten bushels per acre.[1]

175. Williams's method. The method of corn breeding as above outlined has been criticized on the ground that little or no attention is paid to the productiveness of the plant used as the source of pollen. A new system devised by Professor C. G. Williams, of the Ohio Agricultural Experiment Station, provides for equally careful selection of the staminate and pistillate parents. The system in its barest outlines, as stated by Professor Williams, provides for

1. The usual ear-row test. Only a portion (usually about one half) of each ear is planted. The remnant is carefully saved, and when the ear-row test has shown which ears are superior, recourse is had to the remnants to perpetuate these ears in a later season.

2. An isolated breeding plot in which are planted the four or five best ears as demonstrated by 1. *Not the progeny* of the best ears, but the *original ears*. Usually the best ear is used for staminate plants and planted on each alternate row in the small breeding plot. All the plants from the other ears going into the plot are detasseled.

The pedigreed strains produced in the breeding plot are multiplied for general field use and also furnish ears of varying worth for a second ear-row test, if it is desired to continue the improvement.

The ear-row test need not be isolated, for no seed is taken from it. Neither is there any need for detasseling until the breeding plot is reached.

176. Hybridizing. As has already been shown (sects. 13 and 127), seed production is the result of fertilization of the egg within an ovule by a pollen grain. Usually the pollen and the ovule concerned in fertilization are derived from plants of the same species. Often pollen of another species is

[1] For details about corn breeding see De Vries, Plant Breeding, The Open Court Publishing Company, Chicago; *Bulletin 100*, Illinois Agricultural Experiment Station; and *Circular 66*, Ohio Agricultural Experiment Station.

of no use in fertilizing, but sometimes it succeeds perfectly,[1] as when pollen from one species of plum is used for pollinating flowers of another species, or when one parent flower is a plum and the other a cherry, or one a plum and the other an apricot. Any plant grown from seed thus produced is called a *hybrid*. The terms *hybrid* and *hybridization* are also coming to be generally used in cases of breeding between varieties as well as between species. *Crossing* is another term used instead of *hybridization*, and the result of the process or hybrid is called a *cross*.

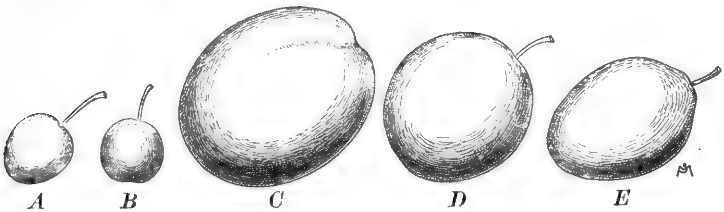

Fig. 160. Results of hybridizing plums

A, a stoneless wild plum; *B*, *C*, *D*, *E*, fruits of seedlings obtained by crossing *A* with the French prune. About one half natural size. Modified from a photograph by Burbank

Hybrids are often extremely variable (figs. 160 and 161), and for this reason it has become a common practice to hybridize plants for the sake of getting a variety of new combinations of characters in the hybrid seedlings, and then to select the desirable kinds for breeding purposes. Until recently it was supposed to be impossible to predict the way in which the characters of the parents would be inherited by the successive generations of hybrids. But a law known from its discoverer as *Mendel's law* often enables the breeder to foretell the characters which the hybrid plants will inherit. Gregor Mendel,

[1] The plants grown from seed which was the result of pollination between different species are often vigorous but incapable of producing seed. This sterility of plants bred by cross-pollination between different species is so common that it was formerly often used as a test to determine whether two kinds of plants that seemed to be different species were really such or were only varieties.

the first successful investigator of the mode of inheritance in hybrids, was an Austrian monk, who carried on his researches in his monastery garden for eight years and published his results in 1865. His discovery was little noticed for about thirty-five years, when it quickly became generally known to biologists everywhere. Mendel's law is not quite simple enough to be stated and illustrated in an elementary botany for secondary schools.[1]

177. How hybrids are artificially produced. Hybridizing, or crossing, plants, is sometimes an easy, sometimes a rather difficult, process. It is simplest in unisexual flowers — for example, in those of Indian corn. Here the tassel (fig. 126) is a

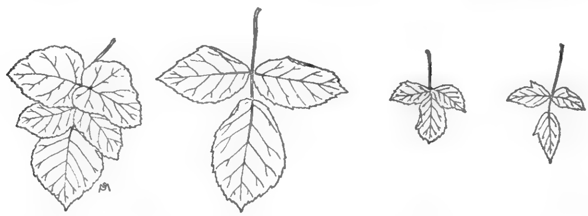

FIG. 161. A few of the many leaf forms of different hybrids between the blackberry and the raspberry

Modified after photograph by Burbank

cluster of spikes of staminate flowers, and the ear (fig. 127) is a spike of pistillate flowers, each thread of the silk representing a stigma and style attached to an ovary (grain of corn). In hybridizing corn it is only necessary to tie a paper bag over the ear before the silk appears, in order to keep off stray pollen, and leave it covered until full-grown, then remove the bag, dust the silk thoroughly with pollen from tassels of the desired crossing variety of corn, and thereafter keep the ear covered until the silk is entirely withered. Sometimes in hybridizing corn the stalks are detasseled just before the ears are ready to receive pollen. If all the stalks of one

[1] See R. C. Punnett, Mendelism, The Macmillan Company, New York. Also L. H. Bailey, Plant-Breeding, The Macmillan Company, New York.

kind or of one row are thus detasseled, it is made probable that pollen, if received at all by the ears of the detasseled stalks, must come from another row or from another kind of corn. The detasseling of alternate rows is a rather common way of insuring cross-pollination. In most cases of hybridizing with bisexual flowers it is necessary to carry out processes similar to the following ones:

1. Select the flower to be pollinated before it opens or before its own pollen is mature. If it is one of a cluster of flowers, as in the wheat and the apple, remove from the cluster of the flowers all that are not to be operated upon.

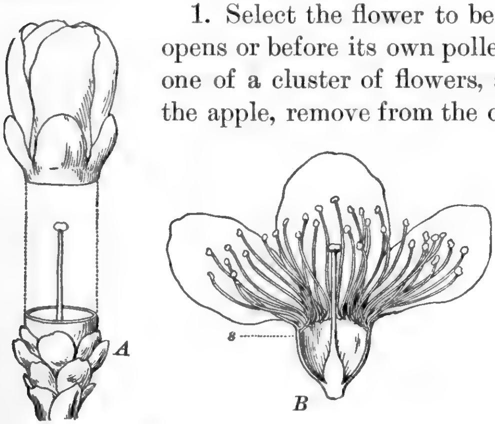

Fig. 162. A peach flower prepared for hybridization

A, flower cut round for removal of the stamens, with the removed parts of the young flower showing above; *B*, longitudinal section of a flower showing level (*s*) at which the cut was made in *A*

2. Open the remaining flowers and remove the stamens by taking hold of the filaments with fine forceps, or cut away all the stamens at once, as shown in figure 162. Keep the flower or the entire twig covered with a paper bag until the stigma is mature.

3. When the stigma is mature, pollinate it with the desired kind of pollen. This may be done with the finger tip or with a camel's-hair brush or other implement. It is safer to take pollen from a flower that has been kept covered with a paper bag to keep off foreign pollen.

4. Keep the pollinated flower covered with a paper bag until the fruit has grown considerably.

178. Plants grown from hybrid seeds. When seeds produced by hybridization are planted, the seedlings grown from them may vary greatly in their vegetative characters, as size,

habit of growth, and form of root, stem, or leaf (fig. 161). They may show much variation in the flowers or in the fruit (fig. 160). The physiological characters of the seedlings may vary greatly; that is, they may have very different periods of maturity and of hardiness in resisting drought, frost, or disease. If any of the characters of the hybrid are highly desirable, the breeder will try to perpetuate the type. If he is dealing with a plant like the potato or the bulb-bearing plants, which can be propagated by planting the tubers, bulbs, or similar parts, the effort to introduce the new variety will probably succeed; and it is not difficult to propagate new varieties of grapes by cuttings, and apples, pears, quinces, peaches, plums, and cherries by grafting or budding; but in the case of plants which must be grown from the seed the perpetuation of hybrid varieties is often difficult or impossible. Sometimes the seed of the hybrid seedling cannot be made to grow, and sometimes the plants will not come true from the seed, so that the promising hybrid variety is represented only by one plant, which leaves no descendants like itself. Professor L. H. Bailey, one of the highest authorities on plant breeding, has by crossing obtained about a thousand wholly new types of pumpkins and squashes, and never succeeded in perpetuating a single one.

179. Instances of successful hybrids. A few successful varieties of wheat and corn are the result of hybridization, and more may be expected in the future. Many good grapes are known to be hybrids, and so are probably a few of the best, like the Delaware and Catawba. Some good blackberries and many excellent plums have been obtained by hybridization. Citrous fruits have been successfully hybridized.[1] Many of our most ornamental flowers, especially varieties of *Canna*, *Amaryllis*, and *Gladiolus*, together with great numbers of orchids, are hybrids.

180. Some rules for plant breeding.[2] Neither the science nor the art of plant breeding can be taught wholly from

[1] See *Yearbook of the Department of Agriculture*, 1904.

[2] See L. H. Bailey, Plant-Breeding, Lecture III. The Macmillan Company, New York.

CHARLES DARWIN

Charles Darwin (b. 1809; d. 1882) for twenty-two years collected data upon problems of competition, variation, survival, and heredity; then (1858), together with A. R. Wallace (b. 1822; d. 1913), presented his essay, "Origin of Species, or Preservation of Favored Races in the Struggle for Life"; published his epoch-making book, "On the Origin of Species," in 1859, and afterwards published many volumes containing a great mass of data bearing upon the evolution of plants and animals. Darwin was an unsurpassed investigator; his rule of observing without prejudice and of adopting no conclusion except on a basis of observed facts, his fearlessness in following truth, his revulsion at known error, furnished an invaluable contribution toward the scientific method of study in biology

books. Careful study of the gardens or fields of some successful breeder is also necessary. The five rules which follow are here given only to illustrate some of the precautions necessary to insure success.

1. For breeding experiments choose plants like wheat, corn, and apples, which naturally show many varieties or elementary species (fig. 163).

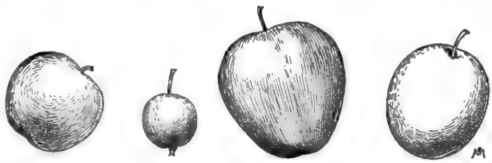

FIG. 163. Four extremely unlike varieties of apple selected from thirty-six varieties, all seedlings of the Early Williams apple

Modified from photograph by Burbank

2. Breed for one character at a time; that is, do not try to get such a product as a strawberry which shall surpass most others in size, sweetness, bearing qualities, and ability to stand shipping long distances — all the desirable qualities in one berry.

3. Do not try to get opposite qualities in the same breed. For instance, corn cannot be bred for high percentage of starch and of protein at the same time.

4. Choose plants for seed by inspection as they grow in the field. A melon or a cucumber plant which bears many rather large fruits is likely to be a better parent than a plant which bore only one very large fruit. The total product of the individual should be ascertained by field study, and the vigor and general condition of the plant should be carefully noted.

5. Keep up the type by constant selection of the best individuals for seed, even after breeding has resulted in securing plants that come up to the desired standard. This is absolutely necessary in perpetuating, for instance, the variations which make the difference between the sweetest and the poorest sugar beets; but it is also useful in keeping such elementary species as wheat varieties up to the highest standard, because the seed of a desirable variety might be taken from imperfect or diseased ears and yield a poor crop.

COLLATERAL READING

The names Yearbook, *Farmers' Bulletin*, *Bulletin* . . ., Bureau of Plant Industry, as used in the list given below, all refer to the publications of the United States Department of Agriculture.

A very detailed list of books and articles on plant breeding will be found in Bailey, Plant Breeding. The Macmillan Company, New York. Some titles not already referred to in this chapter are as follows:[1]

General

Yearbook, 1898, "The Improvement of Plants by Selection."
Yearbook, 1906, "The Art of Seed Selection and Breeding."
Farmers' Bulletin 334, "Plant Breeding on the Farm."
Bulletin 167, Bureau of Plant Industry, "New Methods of Plant Breeding."
Cyclopædia of American Horticulture, article "Plant Breeding." The Macmillan Company, New York.
Cyclopædia of American Agriculture, article "Plant Breeding." The Macmillan Company, New York.
Davenport, The Principles of Breeding. Ginn and Company, Boston.

Special

Farmers' Bulletin 229, "Production of Good Seed Corn."
Yearbook, 1906, "Corn-Breeding Work at the Experiment Stations."
Yearbook, 1902, "Improvement of Cotton by Seed Selection."
Farmers' Bulletin 342, "Potato Breeding."

PROBLEMS

1. In which kind of plants — annual, biennial, or perennial — can plant-breeding results be most rapidly attained? Why?

2. In what kind of plants — those propagated by seeds or those propagated by vegetative means — are the results of plant breeding most readily perpetuated?

3. If you were asked to originate a new variety of string beans, how would you go to work?

4. Is plant breeding easier with plants that have many well-defined and permanent varieties or with those that have no such varieties? Illustrate.

[1] The number of valuable bulletins published by the agricultural experiment stations of the several states is so great that no attempt is here made to cite them.

5. Give examples of plants that "come true to seed" and of others that do not. How does this determine the mode of plant breeding necessary in each case?

6. How do you account for the fact that there are so many slight differences in long-known varieties of cultivated plants, as Baldwin apples, Crawford peaches, Bartlett pears?

7. In saving seed corn of a valuable variety, what can you do to keep the quality up to the highest point? Name several points to be attended to. Send to your state agricultural experiment station for reports upon the change in yield produced by proper selection of seed.

8. Why is it important for seed corn but not for wheat that plots of different varieties should be kept widely separated.

9. If you were to undertake to hybridize the following plants, which would be the easiest to manipulate and which the most difficult? Give reasons. Thistle (fig. 111), willow (fig. 105), arum (fig. 132), grape (fig. 120), corn (figs. 126 and 127).

10. If you succeeded in hybridizing two species of tulips, *A* and *B*, could you propagate the hybrid by planting the bulb matured during that season? Give full reasons for your answer.

CHAPTER XIII

HOW PLANTS ARE CLASSIFIED

181. Introductory. In preceding discussions we have often had occasion to speak of closely related plants which, while different in some ways, were sufficiently similar to enable us to recognize their likeness. Thus we speak of different kinds of grasses, different kinds of corn, or different kinds of oaks. Also, in actual practice many other bases of grouping are used, as is suggested when we speak of agricultural plants, tropical plants, desert plants, water plants, and poisonous plants. Similarity in structure offers a basis of classification that is commonly used. By means of this basis plants that resemble each other most closely are grouped together; then the groups having the closest resemblance are combined into a larger group, until finally all the larger groups compose the last and largest group — the plant kingdom.

182. Oaks as illustrations. A good illustration of the smaller groupings of plants may be had by referring to some of the common oaks. In various parts of the United States we find the white oak, bur oak, red oak, black oak, blackjack oak, live oak, and many others. There are certain special or specific differences between these oaks, as is shown by their acorns and leaves (fig. 164), and each specific kind of oak is called a *species* and has a species name, as *alba* (white), *rubra* (red), *macrocarpa*[1] (bur), etc. Furthermore, these and all the other species which we call the oaks are grouped together into one *genus* (or kind), the genus name of the oaks being *Quercus*. Therefore a genus consists of the different

[1] The original meaning of *macrocarpa* is "large-fruited," or "large-seeded."

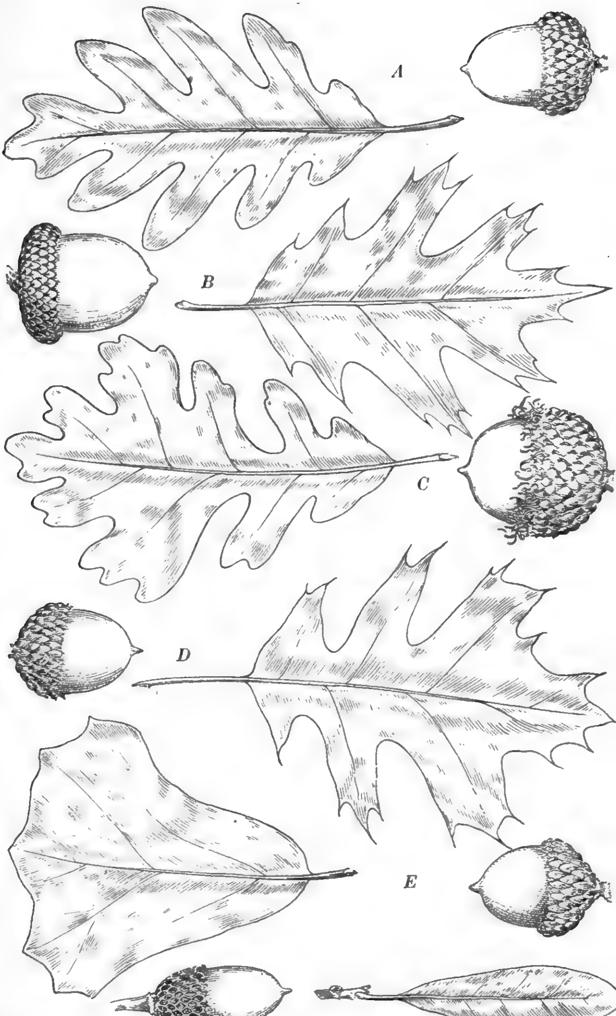

Fig. 164. A group of leaves and acorns illustrating some of the differences between six species of oak (*Quercus*)

A, the white oak (*Q. alba*); *B*, the red oak (*Q. rubra*); *C*, the bur oak (*Q. macrocarpa*); *D*, the black oak (*Q. velutina*); *E*, the blackjack oak (*Q. marylandica*); *F*, the live oak (*Q. virginiana*). The acorns are about three fourths natural size and the leaves less than one half natural size. Modified from R. B. Hough

species that belong to it. A careful study of figure 164 will give some notion of the relative resemblances of two structures in these six species of *Quercus*. In speaking of plants it is customary to use both genus and species name (that is, the binomial system of names), as *Quercus alba;* or, more often, we use the common name, as *white oak*. Elementary botany formerly concerned itself chiefly with attempts to learn the genus and species names and the proper classification of seed plants. We are now concerned more with how plants live than with what their botanical names are.

183. The leading groups of plants. Those genera (plural of *genus*) which resemble one another are grouped together into a *family;* families with sufficiently close resemblances are grouped into an *order;* orders are grouped into *classes;* and classes into *great groups*. A study of the following divisions of the plant kingdom will enable you to see the relations that these divisions bear to one another, and the relations of genus and species names to the whole plan of classification.

Plant kingdom
- Great groups
  - Classes
    - (Sometimes sub-classes)
      - Orders
        - Families
          - Genera
            - Species
              - (Sometimes varieties)

The four great groups of plants are

Spermatophytes, the seed plants in which are:
- *Angiosperms*, or plants with inclosed seeds;
- *Gymnosperms*, or plants with exposed seeds.

Pteridophytes, the fern plants, including the common ferns and other fern-like plants that are not so common.

Bryophytes, including liverworts and mosses.

Thallophytes, including the lowest and simplest plants — the fission plants, the algæ, and the fungi.

Some of these groups will be very briefly considered in the chapters immediately following.

ASA GRAY

Asa Gray, foremost American botanist of the nineteenth century (b. 1810; d. 1888), was trained to be a physician, but relinquished medicine for botany. He taught during the school year, made collecting trips in summer or worked in European botanical centers, and built up the famous Gray Herbarium of Harvard University. As professor of botany at Harvard from 1842, he taught many of the older botanists of the present generation. In 1836 he began a series of elementary textbooks, which were widely used for more than fifty years. His many botanical publications are chiefly systematic. A great teacher, a close friend of his students, a constant worker and author of admirably written scientific and popular articles, he is the most important figure among the founders of botany in America

184. Divisions upon bases other than structure. As already suggested (section 181), plants may be grouped upon the basis of their place of living or mode of life. Also, sub-divisions of the study of plants may be designated by the particular point of view that is kept in mind in pursuing the study. The study of the classification of plants into their proper groups and the determination of their proper generic and specific names is called *taxonomy*, or *systematic botany*. When emphasis is placed upon a comparative study of plant organs and their relationships, the study is known as *plant morphology*. Special study of the cell is *cytology*. Plant activities or work and their relations to the immediate surroundings of the plant are included in *physiology*, while the relationships of plants to one another and to the environment in general is *ecology*. One phase of ecology deals with the distribution of plants over the earth and is known as *ecological plant geography*. The study of plant diseases is known as *phytopathology*, or *plant pathology*. A study of the bacteria constitutes *bacteriology*. A consideration of the useful or harmful aspects of plants is included under the general term *economic botany*, and under this head there are such sub-divisions as *agricultural botany* and *horticultural botany*. These are but the leading aspects under which plants may be studied.

It is evident that these divisions have no sharply marked lines between them, and that they are not all made upon the same basis. For example, we might study the bacteria with reference to their structure, which would be morphology; or in their relation to disease, which would be pathology; or in their relation to farm and garden crops, which would be economic botany.

185. Names necessary as labels. In the following chapters we shall study a few representatives of the leading great groups of plants. It is necessary to have specific names for the plants that are used as illustrations of these groups, for sometimes the plants used do not have common names, and sometimes the common names, when used, are applied to two

or more different species of plants. We must, however, keep in mind the fact that what we really want to find out is not primarily the names of plants, but what plants are, how and where the different groups live, how they reproduce themselves, and how their habits of living are related to the life of other living things. We must have definite names for plants and for their parts in order to be clear when we speak of them, just as we need names for different people in order that we may designate them in a definite way, although we are more interested in what they are and what they do than in their names.

CHAPTER XIV

THE BACTERIA

186. What are the bacteria? When a dish of water in which cut flowers have been kept for several days is carefully examined, a thin film, or scum, may often be found on the surface of the water. This surface film usually consists of many millions of bacteria. The bacteria have thrived upon the plant substances which were dissolved in the water. The bacteria also produce the unpleasant odors that often arise from such a dish of cut flowers. If but a few bacteria had gathered at the water's surface, they could not be seen except by the use of very great magnification, but when such large numbers accumulate in one place, they may easily be seen, just as it is easier to see a pile of sand than it is to see a few grains of sand.

The bacteria are extremely simple one-celled plants. The fact that they are plants was not generally recognized until within the past few decades. Although this group of plants is still imperfectly known, much has been learned of their very great hygienic importance. It has been popularly supposed that all or nearly all of the bacteria are causes of disease, although it is now believed by scientists that very few of them are disease-producing. On the other hand, there are many kinds of bacteria that live in such ways as greatly to aid in important processes upon which men depend.

187. The size and structure of the bacteria. The bacteria are so small, and there are so many kinds of them,[1] that it is not easy to give a clear answer to the question as to what they are. Indeed, they are so small that the figures given for

[1] It has been estimated by Migula, a good authority, that there are at least 1272 distinct species of bacteria.

their size are almost meaningless. When we say that average rod-shaped bacteria are about $\frac{1}{10000}$ inch ($\frac{1}{400}$ mm.) long, and $\frac{1}{25000}$ inch ($\frac{1}{1000}$ mm.) in thickness, we are describing dimensions so small that we cannot appreciate them. It must also be kept in mind that many kinds of bacteria are smaller than the dimensions given above. These figures mean more when we calculate the number of average bacteria that might be contained in a vessel measuring a cubic inch, or when we measure the thickness of a finger nail and estimate how many bacteria, piled one upon another, would be required to make a column as high as the finger nail is thick. Such estimates will make it quite clear that bacteria are small enough to be everywhere and yet escape our attention. Bacteria are of three different forms. Most of them are rod-shaped, or of the *bacillus* form, some are *spherical*, and still others are *spiral* in form (fig. 165). The rod bacteria vary in length and in diameter. Similarly, spherical bacteria vary in size, and some spiral forms may consist of less than one complete spiral, others of a dozen or more spirals.

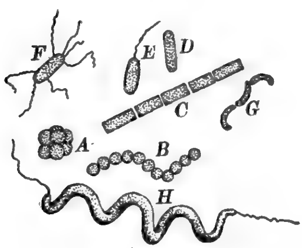

FIG. 165. A group of bacteria illustrating type forms

A, spherical bacteria gathered into a colony, and *B*, spherical bacteria arranged in a chain; *C*, *D*, *E*, and *F*, rod, or bacillus, bacteria, *E* and *F* having cilia; *G* and *H*, spiral bacteria, the former less than one complete spiral, and the latter several spirals. Rearranged after Jordan

Little is known about the structure of these minute plants. The definitely organized cell wall contains a small amount of protoplasm, which sometimes forms extruding cilia (fig. 165). By means of these cilia some kinds of bacteria are able to swim, and some of them move with a speed (over two thousand times their own length in one hour) which is remarkably rapid in proportion to their small size. Definite nuclei have not been seen in bacteria, but it may be that certain granular fragments represent the nucleus. We are more interested, however, in how bacteria live than in their structure.

188. How bacteria secure their food. Since they are so simple in structure, and since they live in direct contact with their food supply, the bacteria absorb their nourishment directly through their cell walls. Different kinds of bacteria may live upon different kinds of organic matter, but almost every kind of organic matter may serve to nourish some kind of bacteria. Certain kinds of bacteria can thrive only in absence of free oxygen, and a few others can construct food somewhat as green plants do. It must also be noted that bacteria, like other living things, produce and excrete substances which, if retained, would be injurious to them. If excreted and accumulated about the bacteria in great quantity, these substances would soon kill them. If a jar of beef broth is carefully sealed after any ordinary bacteria have been introduced into it, there will at first be a rapid increase in their number, and the liquid will become clouded with the organisms and their products. But the excretions soon accumulate to such an extent that the bacteria can no longer grow. They become dormant or may die and settle to the bottom of the jar or collect in a jelly-like mass at the surface.

189. How bacteria reproduce themselves. When in favorable nutrient material, bacterial cells divide frequently. A plant thus forms two new ones, each of which may soon (in from twenty minutes to half an hour) divide again. This is the simplest possible method of reproduction, consisting merely of the dividing, or fission, of a single-celled plant. The possibilities of this rate of reproduction are enormous. If all conditions were to remain entirely favorable for reproduction, a bacterium which divides but once an hour would in two days produce offspring numbering 281,500,000,000, and "in three days the progeny of a single cell would balance 148,356 hundred-weight."[1] Of course it is well known that ordinarily this rate of reproduction cannot be realized, because growth conditions do not remain favorable. The food supply

[1] Jordan, E. O., General Bacteriology, p. 62. W. B. Saunders Company, 1911.

is soon exhausted, and the excretions from the bacteria themselves interfere with their growth and reproduction. But in situations where bacteria can grow they really do reproduce themselves and increase their number with astonishing rapidity (fig. 166). The possibilities of production and growth of large

FIG. 166. Gelatin culture of bacteria

The sterilized gelatin in the dish was exposed in the hallway of a schoolroom for five minutes, and then kept covered for five days, during which time the different colonies of bacteria grew. Each colony grew from one, or possibly, in some cases, from a few individual bacteria, and the number of bacteria that have grown in each colony is so large that the colony is easily seen

numbers are evident when we remember that many millions of bacteria could live for a considerable time in a cubic inch of milk or beef broth.

In a few kinds of bacteria the interior of the cell sometimes becomes rounded and inclosed by a relatively heavy wall. This heavy-walled body may remain inactive for a long period,

and, upon the return of favorable conditions, may grow and produce the kind of cell which formed it. Such specially produced reproductive cells are called *spores*. They often enable the bacteria and other plants to live through periods of unfavorable conditions — as drought, lack of proper air, absence of suitable food, and unfavorable temperature. Some kinds can withstand freezing or boiling temperatures. It is much more difficult to destroy the spores of bacteria than the vegetative, or growing, cells. There are very few spore-forming bacteria among those that produce diseases of men. This is fortunate, since the problem of combating disease would be much more complex if all the harmful bacteria should be able to form these resistant spores. A disease known as anthrax offers a good illustration of the way in which spore formation may increase the distribution of disease. Anthrax is a very destructive disease, as is shown by the fact that, prior to the use of the treatment devised by Louis Pasteur, France in single years has lost as much as $20,000,000 worth of cattle and sheep. The disease also affects men and may cause their death, as it does that of cattle, sheep, and other animals, in from a few hours to a few days after infection. The spores of anthrax form only when the bacteria are exposed to the air. When an animal dies of anthrax, if its body decays while exposed to the air, millions of anthrax spores are formed. These spores can lie in the field for very long periods, probably several seasons, and withstand the variations in temperature, moisture, and light. When they are introduced into the alimentary tract of an animal, they soon reach the circulatory system, where they grow with surprising rapidity and may soon cause the death of the newly infected animal. The desirability of the complete destruction of bodies of animals that have died of anthrax is evident.

190. Bacterial decay and its significance. The bacteria and certain other dependent organisms (as molds, yeasts, and many animals), while living upon the bodies or the products of plants and animals, use parts of them as food. The processes

of securing this nutriment result in partial or complete breaking down of the food substance. This is known as decay. While a body is undergoing decay, usually several kinds of bacteria and other organisms live in turn upon it. In complete decay all of the nutrient organism is used as food, or passes into the air as gases, or is dissolved in water and carried into the earth or into streams. The materials that result from decay are not only directly the remnants of the original plant or animal body, but may also contain excretions from decay-producing organisms. Furthermore, many of these organisms of decay have themselves died and decayed.

Processes of decay are of great biological importance. It is necessary to have the dead bodies and the waste products of living bodies reduced to a form that makes their removal possible. The materials that are broken down are thus made usable for the future growth of plants and animals. Without decay all usable food material would eventually be rendered unavailable for the future growth of plants and animals, so that life on the earth would cease. The earth's supply of food materials would be locked up in organized plant and animal bodies.

It has long been known that the introduction of decayed and decaying organic matter into soils enables them to sustain a more luxuriant vegetation. Undecayed organic matter is not available for agricultural or horticultural plants. Such material must await more complete disorganization before it can be useful. It is desirable to regulate this decomposition so that the largest possible amount of its products may be retained in the soil. This is one of the problems of scientific agriculture (see Chapter XIX). For example, if stable manure in large masses is allowed to heat under the rapid destructive action of the bacteria and other living things which flourish in it, much valuable ammonia is given off into the atmosphere and lost. Slower decay, especially if underground, wastes but little ammonia.

191. Bacteria and soils. In an earlier part of this book we learned that nitrogen compounds are necessary for the construction of part of the food which plants must have. In the

preceding section the relation of decay to soils was suggested. Although the relation of plants and soils is more fully discussed in a later chapter, it is advisable at this point to discuss briefly the relation of bacteria to soils. Their methods of living bear peculiar relations to the nitrogen supply of the soil.

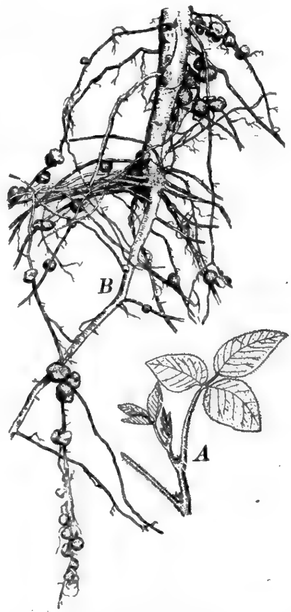

FIG. 167. Bacterial tubercles on the roots of the cowpea [1]

A, leaves of the cowpea; *B*, part of the root system of the cowpea, with numerous tubercles, the tubercles being induced by bacteria which gather nitrogen from the air of the soil. One third natural size

There are at least four groups of soil bacteria which are of interest in this connection. First, there are saprophytic forms which in their processes of nutrition make a compound of nitrogen and hydrogen which is known as ammonia. This bacterial action is known as ammonification, which means "ammonia-making," and the bacteria which are responsible for the action are called the ammonification bacteria. Second, there are the so-called nitrite bacteria, which in their process of nutrition change ammonia into other compounds in which there is one part of nitrogen to every two of oxygen. Such compounds are called nitrites. Third, there are the nitrate bacteria, which change nitrites into compounds in which there is one part of nitrogen to every three of oxygen. Such compounds are known as nitrates. These last two processes are spoken of as nitrification. Fourth, there is a still different and most important group of bacteria which enter the roots of certain kinds of plants, as clover, soy beans, peas, and alfalfa. When some of these bacteria have entered the roots, they become surrounded

[1] From "Nitrogen Bacteria and Legumes," *Bulletin 94*, S.C. Exp. Sta.

by tissue, so that they form nodules, or tubercles (figs. 167 and 168). Within these tubercles the bacteria are able to take the uncombined nitrogen from the air of the soil and combine it with other substances in such a way as to form nitrates. The tubercle bacteria are known as the nitrogen-fixing bacteria, since they take free nitrogen from the air and combine it with other things so as to make plant foods.

Since the ordinary grain-producing plants must have nitrogen in order to grow, and since they can use it only in the nitrate form, the significance of these tubercle bacteria to agricultural plants is evident. Agriculturists have known for a long time that, after growing a crop of clover or peas, the soil is in better condition for growing other crops, but the way in which this is brought about, and the relation of bacteria to the process, are matters of recent knowledge. The clover, alfalfa, peas, and beans grow better when the tubercle bacteria are present (fig. 169), and the added nitrates left by decay of the tubercles and the plants upon which they grew enrich the soil for subsequent crops.

FIG. 168. Bacteria, or bacteroids (meaning "like bacteria") which grew in the root tubercles[1]

There are many other kinds of soil bacteria, one kind living in such a way as to denitrify nitrate compounds, thus working in a manner opposite to some of the above groups.

192. Bacteria and the destruction of foods. From what has been said in preceding sections it is evident that all our fruits, vegetables, meats, etc. are at times in danger of destruction by bacteria or other organisms. How to prevent this destruction has been one of the important problems since civilization began. Surplus production of food is useless unless some of it may be kept for future needs.

[1] From Lipman, Bacteria in Relation to Country Life. The Macmillan Company.

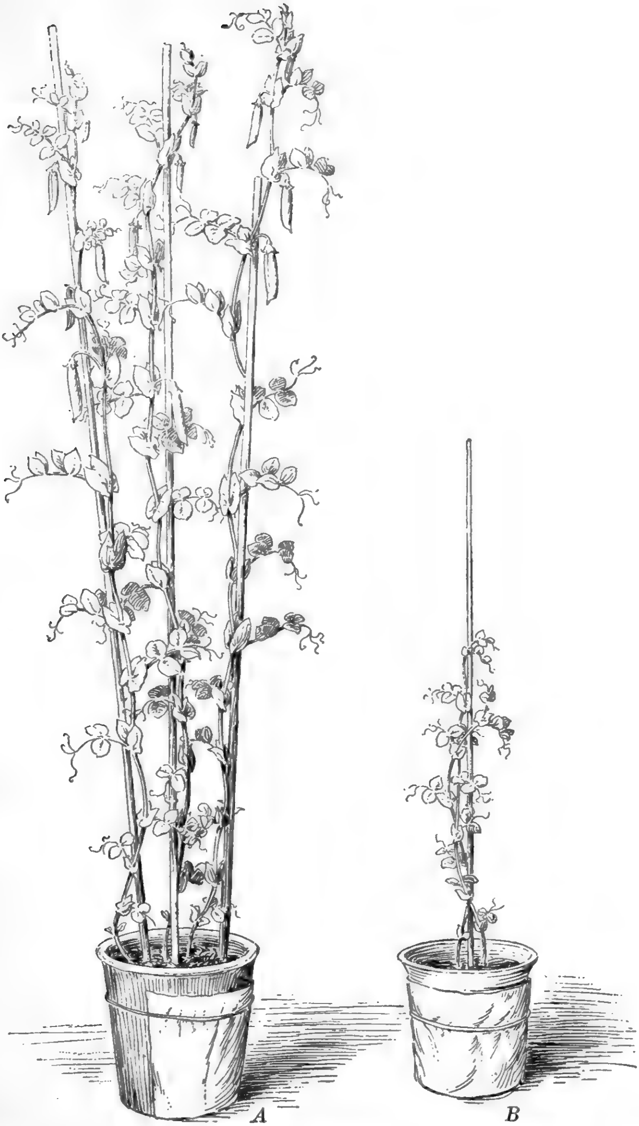

Fig. 169. Cultures of peas of the same age and from the same kind of seed, one (*A*) with root-tubercle bacteria and one (*B*) without. After Frank

In the preservation of fruits much progress has been made by improvements in methods of gathering them. Most fruits have a natural covering, which, if unbroken or unbruised and kept clean, will for a long time prevent the entrance of organisms of decay. If two sets of ripe apples are gathered — one carelessly, so that bruising and scratching of the surface occurs, the other with sufficient care to avoid these injuries — and both are kept under similar conditions, an interesting demonstration will be made of the desirability of proper care in handling fruit.

193. Refrigeration and drying. Long before it was known how decay is produced, it was known that low temperature and drying would prevent decay. Refrigeration has now become the chief method of preventing decay, since bacteria do not thrive at or below the freezing point. There is doubt whether bacteria grow at all when at freezing temperature, but this point is not definitely settled. Foods are kept for years by cold or by drying, and are thus shipped all over the world. Fruits, meats, and grains, when completely dried (a natural process of preservation), may be kept for years, since destructive bacteria cannot thrive upon thoroughly dry food. Preservation in salt and sugar or their strong solutions serves the same purpose as drying, since salt and sugar have such avidity for water that destructive organisms have their protoplasmic water extracted and therefore cannot grow. Fish, beef, pork, and other meats may be preserved by smoking with wood smoke. The creosote that is carried into the meat by this process helps to prevent the growth of destructive organisms. This method of preservation, though thoroughly wholesome, requires long exposure to the smoke. It is not so extensively used for beef and pork as formerly, though large quantities of fish are still preserved in this manner.

194. Sterilization and canning. High temperature may also prevent the growth of bacteria, and by its use sterilization and canning have recently offered very great opportunities for food preservation and shipment. By means of heat properly applied all bacteria and other organisms of decay may be

killed. If such completely sterilized food is hermetically sealed in vessels that have been similarly sterilized, it will not decay. It is difficult, but entirely possible, to thoroughly sterilize both food and sealing appliances so that absolutely no organisms will grow.[1] Other methods of preservation by the introduction of chemicals (antiseptics) that prevent the growth of bacteria are sometimes used. These chemical preventives are poisons. If eaten in very small quantities, injurious results may not be immediately noticeable, but the use of these preventives is attended by constant danger. Milk, meats, and confections that are so preserved should always be avoided.[2]

195. Preservation of milk and water supply. The relation of bacteria to milk and water supply is a subject of the greatest importance. A rather large number of harmless bacteria may often be found in reasonably pure milk and water, but careless handling of bottles and cans, or the use of tuberculous cows, may result in widespread disease. If milking is done through absorbent cotton or through several layers of cheesecloth, used as a cover for the milk pail, most of the impurities are caught in the strainers. Milk pails and shipping cans and milk bottles should always be sterilized before they are used. Milkmen who were otherwise fairly careful in their work have been known to rinse their pails and cans in polluted wells or streams. Bacteria which produce various kinds of disease have thus been distributed. Either milk or water may be sterilized by boiling, and may be kept sterile if placed in sterile vessels. Both, however, are better if they can be kept in a pure condition without sterilization. An efficient method of preserving milk is by pasteurization,[3] in which the

[1] Abel, Mrs. Mary Hinman, "Care of Food in the Home," *Farmers' Bulletin 375*, U.S. Dept. Agr., 1909.

[2] Sometimes in canned goods, stale meats, and other foods, poisonous substances known as ptomaines are formed. It is supposed that they are produced as secretions from bacteria, as results of chemical change or decay of such foods as meats and fruits, or even from the disorganization of some of the bacteria.

[3] "Directions for the Home Pasteurization of Milk," *Circular 152*, Bureau of Animal Industry, U.S. Dept. Agr., 1912.

vessels containing the milk are placed in water and brought to a temperature of 150° to 155° F., and then cooled and kept cool until used. This method kills most of the bacteria in milk and makes less change otherwise than does boiling.[1]

Bacteria are important in connection with many other industries. The formation of acetic acid (the acid of vinegar) is due to the growth of several kinds of bacteria. Part or all of the processes of curing tobacco, tanning leather, preparing plant fibers (as flax and hemp), and making butter and cheese depend upon the growth processes of different kinds of bacteria.

196. Bacterial diseases of plants and animals. Although many bacteria grow constantly upon and within other plants and animals, these are usually not disease-producing bacteria. Sometimes, however, malconditions in the host plant or animal are produced by bacteria, and disease and death of the host may result.[2]

Brief reference to a few kinds of bacterial disease will afford illustrations of some of the effects produced upon plants and animals (fig. 170). In the case of black rot of cabbage the bacteria enter the cabbage leaf through the leaf pores. Once within the leaf, they grow rapidly, and brown or black spots appear on the leaf as outward evidence of the inward ravages of the parasites. These leaves may become shriveled. The disease may spread throughout the plant and result in destruction of the entire head of cabbage.

"Pear blight" is a disease which often seriously affects the leaves, young twigs, and fruit of the pear and apple. The bacteria cannot live under long exposure to direct sunlight

[1] "Care of Milk on the Farm," *Farmers' Bulletin 63*, U.S. Dept. Agr., 1906.

"Bacteria in Milk," *Farmers' Bulletin 348*, U.S. Dept. Agr., 1909.

"Sources of Bacteria in Milk," *Bulletin 51*, Storrs Agr. Exp. Sta., Storrs, Conn., 1908.

"Milk and its Products as Carriers of Tuberculosis Infection," *Bulletin 143*, Bureau of Animal Industry, U.S. Dept. Agr., 1909.

[2] A few diseases are caused by small animal parasites, but since these are not bacterial diseases, they are not included in this discussion.

or to drying, but can endure low temperatures. During the winter they live in the diseased twigs. In the early growing season the leaves and young growth of the twigs become blackened and soon wilt as a result of the internal growth of the parasite. The bacteria secure nourishment from the cells of the host. They may partially or wholly stop the cellular passages of the host, and are possibly injurious in other ways.

The question of how these bacteria are distributed to new hosts is important. Even if they should be carried through the air, and should withstand the consequent drying and sunshine, and should fall upon the surface of twigs, leaves, or fruit of the proper host, it is said that they could not make their way into the tissue. It is believed that the common method of infection is by means of biting or stinging insects or of nectar-hunting insects that visit the flowers and fruit. When a few bacteria are inserted into a new twig, leaf, or floral structure, the infection may spread several inches, and soon the blighting begins. When one flower is infected, insects may carry the bacteria to almost every flower on the tree or on other trees in the vicinity. Moreover, when the disease has developed far enough for the characteristic gummy exudations to appear, insects that bite into them may become loaded with the bacteria and may insert some of them into a new host. In pruning

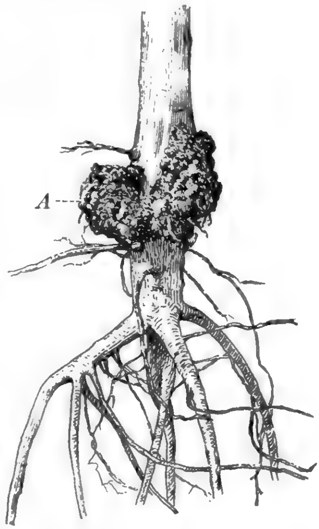

FIG. 170. A crown gall produced by bacteria (*Bacillus tumifaciens*) on young apple tree[1]

A, the tissue of the apple plant which grew around the infected area, thus producing the knotted growth known as the gall. One third natural size

[1] From "Field Studies of the Crown Gall and the Hairy Root of the Apple Tree," *Bulletin 186*, Bureau of Plant Industry, U.S. Dept. Agr., 1910.

both diseased and healthy twigs, the knife may be the means of transferring bacteria. If all infected parts are removed and burned, and if the knife used in pruning diseased twigs is sterilized before being used in pruning healthy plants, the continued spread of the disease is made unlikely.

197. Diseases of man. In the section on nutrition of the bacteria (sect. 188) attention was directed to the fact that excretions are regularly produced by them. In case of disease-producing forms, some of these excretions are injurious or poisonous, and are known as *toxins*. In susceptible plants or animals toxins may produce disease. Each kind of disease-producing bacterium forms its own peculiar toxin or toxins, which in time may produce a particular kind of disease. Substances that neutralize toxins are known as *antitoxins*. In the body of the diseased organism antitoxins are produced which, when formed in sufficient quantities, counteract the influence of the toxins. When one has had an attack of smallpox or diphtheria and has produced sufficient antitoxin to enable him to overcome it, he is usually not susceptible to another attack of the same disease. He is *immune*. There are other diseases (such as mumps, measles, and scarlet fever) against which most people may acquire immunity by once surviving an attack. This immunity is usually lifelong, though exceptions are known. In the case of other diseases (such as typhoid and influenza), one may become susceptible to another attack. Some people are naturally immune to certain diseases.

Smallpox vaccination[1] consists in infecting human beings with organisms that have been grown in such unfavorable ways that their ability to produce disease is greatly reduced. Consequently the result of vaccination is to cause a very mild attack, which produces immunity against fully virulent smallpox. This lasts for a period of years (usually given as seven years), though the protective effect gradually diminishes.

[1] The specific organisms which produce smallpox have not been fully identified. It is thought by some that smallpox is caused by an animal organism somewhat like the malarial parasite, and not by bacteria.

198. Preparation of antitoxin. It has been found possible to secure from horses and mules an antitoxin that will counteract diphtheria toxins in the human body. These animals are naturally immune to diphtheria, but by injecting into their bodies toxins produced in beef broth by diphtheria bacteria, this natural immunity is greatly increased. First into the animal's body there is injected a small amount of toxin. This process is repeated, with an increasing amount, at intervals of a week or a little less, for a period of two or three months. The animal finally withstands, with no ill consequences, an amount of toxin that would have proved fatal if used at first. At this time some of the blood is drawn off and allowed to clot, and the antitoxic serum is sterilized. This antitoxic serum is usually concentrated, in order to make it possible to inject the desired strength of antitoxin without an unnecessarily large amount of liquid. After its relative strength is determined, it is sealed in small bottles and is ready for distribution. A human being who has diphtheria may then be given the proper amount of antitoxin. If it is properly given, and given early enough, the attack is defeated.[1]

AVERAGE ANNUAL DEATH RATE FROM DIPHTHERIA PER 10,000 POPULATION[2]

	Before use of antitoxin (1885–1894)	Antitoxin period (1895–1904)
Paris	6.41	1.49
Berlin	9.93	2.95
Vienna	8.14	2.95
London	4.85	3.88
New York	15.19	6.62
Boston	11.76	6.34
Baltimore	7.34	4.99
Chicago[3]	14.29	5.13

[1] A few inexcusable cases have occurred where impure antitoxin was used.

[2] Jordan, E. O., General Bacteriology, 1911.

[3] The use of antitoxin was begun in 1895–1896; the death rate dropped from 12.01 in 1895 to 7.62 in 1896.

199. Benefits from use of diphtheria antitoxin. Great benefits have come to the human race through the discovery of diphtheria antitoxin. It was generally introduced in 1894. A study of the table on page 213, containing data for ten years before and ten years after the introduction of this remedy, will give an idea of the value of this scientific discovery.

200. Tuberculosis: the great white plague. The disease commonly known as tuberculosis is so generally distributed and so destructive that it has been called "the great white plague." Its universal importance demands that a separate section be given to a brief statement concerning it. It is the most destructive disease that affects the human race, and in the United States it causes about one ninth of all deaths.

The lungs are the organs most frequently attacked, though the bones and joints, the intestines, the throat, the skin, and other organs are often infected. The growth of tubercle bacilli in the body is usually very slow, and months or years may pass before conspicuous consequences follow infection. Furthermore, the bacilli may live upon a handkerchief, in the floor of a house, in a public building, in public-transportation vehicles, or in the dirt of the street, for a very long time, and then grow when they are introduced into the human body. Some of the lower animals (cattle, hogs, and poultry) are subject to tuberculosis and may infect human beings.

Infection is usually through the organs of breathing, though the germs may be introduced into the digestive system in milk and other food. Persons who have tuberculosis may "expectorate from 500,000,000 to 3,000,000,000 tubercle bacilli in twenty-four hours."[1] Also, such persons, while coughing, may inject into the air very small droplets which contain many bacteria, and these may float in the air for a short time. Since the dried or partially dried tubercle bacilli may be transported by the air, it is evident that every precaution should be taken to keep the air from becoming contaminated. Furthermore, it is known that when tubercle bacilli are moist,

[1] Jordan, E. O., General Bacteriology, 1911.

the direct light of the sun has a destructive effect upon them, and that fresh air is likely to contain fewer tubercle bacilli than the close air of rooms in which many people have been. Plenty of fresh air, sunshine, and wholesome food are most important factors in preventing attacks of tuberculosis, and these, together with good general vitality of the body, are the best guaranty against this disease. On the other hand, poor food, bad air, dark rooms, and low vitality render the body a favorable growing place for these germs, when once they are introduced. These predisposing factors are of tremendous importance in relation to tuberculosis. The nature of the occupations and habits of men have much to do with predisposing and exposing them to this disease. In 1898 an Englishman named Newsholme showed by records that for each 100 agriculturists who died from tuberculosis and other respiratory diseases there were 453 potters and earthenware workers, 407 cutters, 373 plumbers, and 335 glassmakers who died from these same diseases.

201. Prevention of disease. Bacteria are distributed into almost every nook and corner of the earth — in soil, air, water, and dust, and upon and within the bodies of plants and animals. Disease-producing bacteria are common, though far less abundantly distributed than forms which do not cause disease. It must be kept clearly in mind that if all disease-producing bacteria from patients who have disease were immediately killed, there would soon be no danger of distribution of disease by any of the ordinary agencies. A good deal is known about the methods of distribution and infection of the most dangerous disease-producing forms, though our knowledge is by no means complete. Polluted water and milk have often been the means of wholesale distribution of typhoid germs (fig. 171). There are numerous records of cases in which the typhoid pollution of rivers has been directly followed by outbreaks of typhoid in cities that get their water from these rivers. There are also instances where typhoid-polluted milk has left a trail of typhoid wherever it was used.

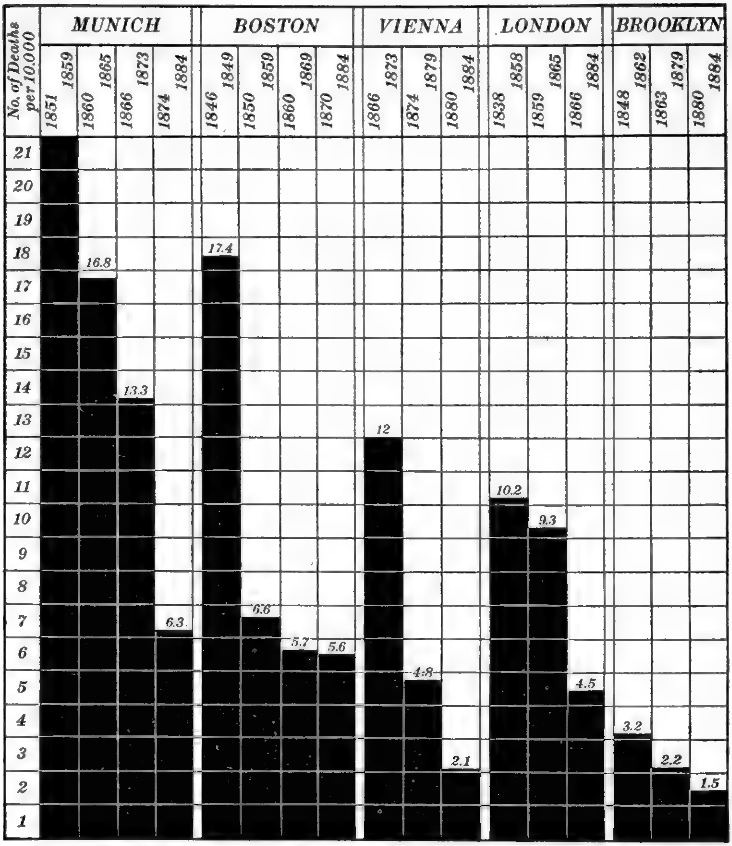

FIG. 171. A chart illustrating the number of deaths from typhoid fever before, during, and after the introduction of improved systems of sewage disposal and water supply

Five prominent cities of the world are selected. The figures indicate the number of deaths for each 10,000 inhabitants. Rearranged from a chart in Abbott's "Hygiene of Transmissible Diseases"

The house fly is a dangerous agent of distribution of typhoid and probably of other disease bacteria. The atmosphere is an efficient carrier of the bacteria of tuberculosis. Every possible effort should be made to remove the breeding places of flies

(refuse from stables, exposed and decaying garbage, etc.) and to keep flies out of public and private dwelling places; to insure a pure and well-kept supply of milk and water;[1] to keep vegetables and other foods that are sold in public places free from dust and flies and promiscuous handling; to disinfect all known or suspected disease-bearing materials of all kinds;[2] to have abundance of fresh air; to have all the sunshine possible, since sunshine is destructive to many disease germs.

202. Importance of high standards. The maintenance of a high standard of vigor is evidently important as a means of preventing bacterial disease. Many people have had disease-producing bacteria introduced into their bodies without any serious consequences — indeed, without even being conscious of danger. They were in such vigorous condition that the initial growth of bacteria was prevented. An instructive experiment relative to this point was performed by Pasteur. Ordinary domesticated fowls are not readily susceptible to anthrax; Pasteur found, however, that if he kept the fowls at lower temperatures than was normal for them, they were very susceptible to anthrax, and that under such circumstances it proved deadly to them. This is a common principle of hygiene. When, through excessive fatigue, loss of proper sleep or nourishment, or any other cause, bodily vigor is greatly reduced, susceptibility to disease is increased.

Modern bacteriology has offered the human race the means of escape from many diseases. Ignorance, lack of care, and financial greed are often the only excuses that can be offered when certain diseases occur. If only those who are responsible

[1] In Germany it is unlawful for filtered water to contain more than 100 bacteria per cubic centimeter, and it should always contain less. Boston has a legal standard which requires that market milk shall not contain more than 500,000 bacteria per cubic centimeter, and Rochester, New York, and Milwaukee, Wisconsin, have legal standards of 250,000 per cubic centimeter. Certified milk should not contain over 10,000 bacteria per cubic centimeter. There is milk in which the number runs from one million to several millions.

[2] In "Bacteria, Yeasts, and Molds in the Home," by H. W. Conn (Ginn and Company), there is an excellent popular discussion of the nature of bacteria and the effects of their growth.

for them were attacked by these preventable diseases, the matter would not be so serious, for in that case disease and the resulting deaths would tend to eliminate those who do not act upon the knowledge of sanitation which we now possess; but many innocent people suffer because others do not take proper precautions against the spread of diseases over which they might have control. As one means of protecting the public many states have laws preventing the use of public drinking cups. Attempts are made to have school children drink from running water, so as to make sure that all contaminated water flows away. We need many more regulations of the same kind in order to guarantee a reasonable security against the needless spread of disease.

PROBLEMS

1. How can you show that the process of decay is of advantage to living things? Would decay take place without the action of dependent organisms?

2. What are the relative advantages and disadvantages of preventing the decay of food by refrigeration and by the use of chemicals? Why are chemicals sometimes used where other means of preservation might be adopted?

3. What are the surest methods of preventing the spread of bacterial diseases of plants, such as pear blight and the black rot of cabbage?

4. Would the fight against typhoid fever be won more quickly by destroying all flies that carry typhoid or by destroying all infecting material from persons who have typhoid?

5. In your school and community what are the chief needs for a better understanding of the nature of bacterial diseases?

6. What are your local regulations in regard to quarantining persons ill with infectious diseases? in regard to preventing the introduction of diseased fruit trees? of diseased animals?

7. What bulletins has your state agricultural experiment station or your state board of health published dealing with the relation of bacteria to human disease, diseases of farm animals, dairying, household industries, or agriculture?

LOUIS PASTEUR

Louis Pasteur, the world's most noted bacteriologist (b. Dôle, France, 1822; d. Paris, 1895), in studying fermentation, was the first to develop accurate methods for securing pure cultures. When the nature of bacterial disease was unknown, he discovered the causes of two destructive diseases of silkworms (from which France had lost sometimes as much as $20,000,000 in one year), proved that the diseases are infectious, and showed how to avoid them. Though partially paralyzed (1868), he devised means of treatment for hydrophobia, taught men the possibility of freedom from disease, and laid the foundation for modern bacteriology and public hygiene. In recognition of his services to the world he was given a gold medal inscribed "To Pasteur, France and Humanity Grateful"

CHAPTER XV

THE ALGÆ

203. Introductory. Since they usually grow in water, the algæ are sometimes spoken of as pond scums, water mosses, sea mosses, and seaweeds. Both fresh and salt waters serve as growing places for the algæ, and they often appear in such abundance that great mats of plants are formed upon or below the surface of the water. There are many different kinds of algæ, and they are divided into four groups, the chief distinguishing character being their color. The most common algæ have a distinctly green color and are known as the *green algæ.* Others, also quite common, have their chlorophyll mixed with a blue coloring matter, so that they are bluish green, and these are known as the *blue-green algæ.* These two groups of algæ are found chiefly in fresh waters. There are two other groups found usually in salt waters. In one of these, the *brown algæ,* there is a brown coloring matter mixed with the green, and in the other, the *red algæ,* the green is obscured by red, which often becomes most striking in its hues.

204. The blue-green algæ.[1] Masses of these blue-green plants may often be seen in pools of stagnant water or upon wet soil. Sometimes they appear as slimy coatings upon sticks, stones, and poorly cleaned watering troughs for farm animals, and they may also appear as free-floating, dirty mats or balls. The blue-green algæ are very widely distributed, and there are many kinds, of which *Nostoc* and *Oscillatoria* are quite common and may serve to illustrate the group.

[1] In structural details blue-green algæ are probably more closely related to bacteria than to other algæ, but because of their general appearance and habits of living they are mentioned briefly with the algæ.

The bluish-green balls (fig. 172, *A*) of *Nostoc* plants are found upon damp soil or floating upon stagnant water. Under magnification [1] the *Nostoc* ball is seen to be composed of granular jelly, interwoven by many chains of cells, each of which is a *Nostoc* plant (fig. 172, *B*). These chains often divide into two or more shorter chains, breaking where there are large, dead cells (*heterocysts*), and each chain proceeds to live as a new plant. *Nostoc* may absorb the materials needed for photosynthesis directly through the cell walls, or it may perhaps absorb organized foods as do the bacteria, since much food of this kind is present in the water in which the plants live. In times of drought the jelly balls dry slowly and may become dry enough to crumble easily, but when a favorable amount of moisture returns, the plants within the ball may proceed to grow.

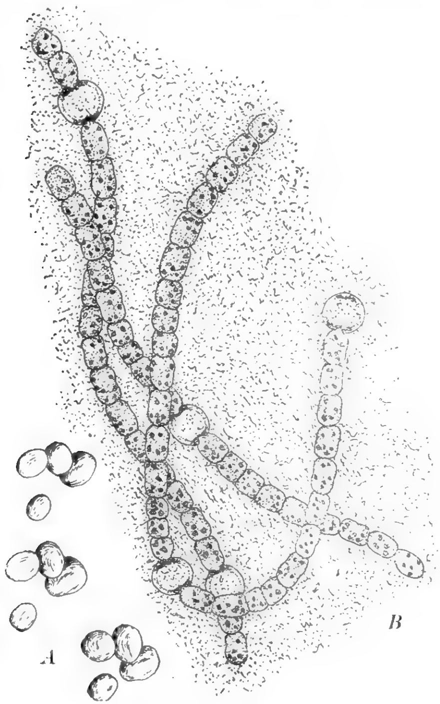

FIG. 172. *Nostoc*

At the left (*A*) are several of the *Nostoc* balls, which appear as glistening, rounded masses (natural size). At the right (*B*), inclosed in gelatinous material, are a few chains of *Nostoc* plants which have been taken from one of the balls and greatly magnified. In the chains several of the enlarged heterocysts may be seen

[1] When beginning the study of the algæ it is often better to use a good specimen under a demonstration microscope than to attempt individual microscopic work. If preceded by preliminary demonstration work the following individual studies will be more intelligible and successful.

Oscillatoria grows in the same kind of region as *Nostoc*, but is more abundant. It appears as floating mats or as slimy coatings upon objects in the water. Frequently sticks and stones on the bottom are covered with a beautiful velvety layer consisting of multitudes of these simple plants. The individual plants are thread-like (fig. 173) and often have a swinging, gliding, or oscillating movement, from which the name of the plant is derived. In stagnant or foul water *Oscillatoria* plants grow vigorously, being able to thrive throughout a wide range of temperature. The cells of the plant divide, thus lengthening the plant. Later the threads break into two or more new threads, each of which continues to grow as an independent plant. The cells of one plant are inclosed in jelly-like sheaths, but there is no jelly mass which holds many plants together, as in *Nostoc*.

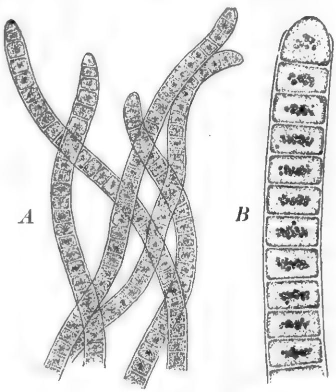

FIG. 173. *Oscillatoria*

A, tips of several plants; *B*, part of one plant, enlarged to show cellular structure. Both magnified, *B* much more than *A*

It is evident that blue-green algæ live and reproduce themselves in very simple ways.

205. The green algæ : *Pleurococcus*. This green alga is very widely distributed and is often called green slime, because of the appearance it presents when growing upon partially shaded tree trunks, fences, rocks, and old buildings. It is not usually recognized as being a plant. When there is abundant moisture in the air, the coating of plants presents the appearance of a coating of green paint upon the surface which supports them.

When examined under suitable magnification, the green slime is seen to be composed of many thousands of single-celled plants. A careful measurement of a number of plants showed their average diameter to be about $\frac{1}{2000}$ inch (.014 mm.). In other words, it would require approximately 500 of these

plants, placed side by side, to make a row that would reach across the unsharpened end of an ordinary lead pencil. How does *Pleurococcus* compare in size with average bacteria?

The spherical plants consist each of a small mass of living material, or protoplasm, surrounded by a cell wall. The protoplasm is so thoroughly colored by chlorophyll that usually it is not easy to see the centrally placed nucleus (fig. 174). Sometimes in these plants special parts of the protoplasm hold the chlorophyll, and each of these is known as a chloroplast, which means "a green body," or a chlorophyll-containing body. Parts of the protoplasm that surrounds the nucleus and the chloroplasts are granular and are called cytoplasm. Some of the internal space of this one-celled plant may be occupied by one or more vacuoles, which are regions surrounded by cytoplasm and filled with air or water.

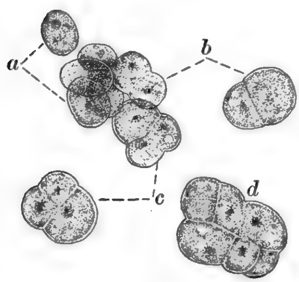

FIG. 174. Green slime (*Pleurococcus*)

a, single plants showing cell wall, granular cytoplasm, and nucleus; *b*, plants in process of reproduction by division, or fission; *c* and *d*, further divisions sometimes resulting in formation of colonies of plants. Greatly enlarged

206. The food of *Pleurococcus*. The bark or other substance upon which *Pleurococcus* grows is often sufficiently moist to provide it with water. Rains and dew supply water intermittently. When dry, the plants remain dormant until conditions again become favorable. Carbon dioxide (and possibly some moisture) may be absorbed directly from the air, and with carbon dioxide and water, and favorable temperature and light, *Pleurococcus* plants may carry on photosynthesis, thus making their own foods. Heat, cold, and extreme drought are some of the severe conditions which this plant must be able to resist in order to live. When plants from any of these extreme conditions are placed in favorable moisture, temperature, and light, they become bright green within a few hours, showing that they are manufacturing foods.

207. Reproduction of *Pleurococcus*. New *Pleurococcus* plants are formed by the division of the old plants. Thus, the growing, or vegetative, plant body (one cell) divides, and each division is a new plant. Under favorable growing conditions reproduction goes on rapidly. The divisions follow one another in such a way that whole colonies, the descendants of one individual, are often grouped together (fig. 174). Obviously *Pleurococcus* is a very simple plant in its structure, nutrition, and reproduction.

208. *Spirogyra*. One of the most abundant of the common floating pond scums is the green alga, *Spirogyra*. The plant is sometimes called "brook silk" because of its soft, silken texture, by means of which it may generally be distinguished from other fresh-water algæ. It is usually very bright green, except when it gathers in dense masses at the surface of the water, when it may be dark yellowish green. *Spirogyra* is a many-celled plant, with cylindrical cells arranged end to end, and all held in a common sheathing plant wall. Also, each cell contains one or more peculiar spirally arranged chloroplasts, each of which extends almost or quite the entire length of the cell (fig. 175). There are different numbers of chloroplasts in the cells in different species of *Spirogyra*. A layer of cytoplasm usually lies just within the cell wall, and strands of cytoplasm run to the nucleus, which is suspended in the central part of the cell (fig. 175).

209. The nutrition and growth of *Spirogyra*. In the water in which *Spirogyra* lives there are dissolved the carbon dioxide and other inorganic materials from which foods are made. Indeed, there is much water within the plant itself, as may be demonstrated by careful drying, by which it is sometimes found that as much as 98 per cent of this plant is water. That photosynthesis is carried on is often made evident by the oxygen bubbles which arise from the plants that are active. It is obvious that this plant can expose more chlorophyll to the light, and hence can do more photosynthetic work, than can *Pleurococcus*.

When *Spirogyra* cells divide, the division wall is at right angles to the length of the plant. This results in an increase in the number of cells and usually in the growth in length of the whole plant. Growth occurs so rapidly that, in a few days after the plants are first seen in the spring, they become so abundant that they pollute the water in which they grow, and it is often necessary to remove these and other algæ, as is seen later (sect. 216).

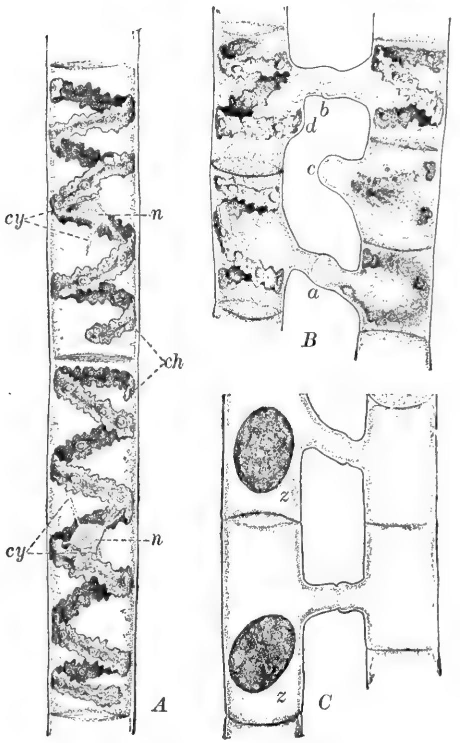

FIG. 175. *Spirogyra*

A, a vegetative cell, showing the form of the cell and of the spiral chloroplast (*ch*), also the nucleus (*n*) and cytoplasm (*cy*); *B*, beginning of conjugation (*a* and *b*), and tubes which failed to conjugate (*c* and *d*); *C*, completed zygospores (*z*)

210. The reproduction of *Spirogyra*. It is possible for a single plant to become broken into two or more pieces, when each one may grow into a new plant; this is vegetative reproduction and resembles the vegetative reproduction that was seen in *Pleurococcus*. But this is not the usual method of reproduction in *Spirogyra*. The cells of two plants that lie near one another may unite in pairs by means of tubes growing out from the walls of both of the uniting cells (fig. 175). These tubes meet and their end walls are absorbed, so that there is a continuous tube

from one cell to the other. Then the protoplasm from one cell passes through this tube to the other cell, and the two masses of protoplasm unite. The nuclei unite and one cell is formed from what were two. About this new cell a heavy wall is formed, and this specially formed structure is a *spore;* that is, a specially formed cell which can reproduce the kind of plant that formed it. It must be noted also that this spore, being formed by cell union and not by cell division, is sexual; also, sexual cells that are formed by union of similar cells are called *zygospores*, that is, yoked spores. It is customary to speak of the cells that unite to form spores as *gametes*, and in the case of the plant *Spirogyra* the gametes are similar, so there need be no special name here for the two gametes, to distinguish them one from another. In asexual reproduction, as will be seen in other plants, reproduction is carried on by means of spores that are formed by cell division, not by cell union.

In two *Spirogyra* plants there may be many cells uniting, or conjugating, at the same time. These pairs are usually in about the same stage of spore formation. Occasionally cells from one plant will unite with those from more than one other plant. Also, occasionally one cell may unite with the adjoining one in the same plant. When ripe, the zygospores are set free by the decay of the old walls and may fall to the bottom of the pond or stream. After a period of rest, sometimes after a drought or in the spring, these spores germinate and produce new *Spirogyra* plants. It is obviously an advantage to the plant to have a heavy-walled spore to carry it through unfavorable periods.

211. A branching alga: *Cladophora*. This is a green alga of very wide distribution. It usually grows attached to objects along shoals in streams, over dams, and about waterfalls. Sometimes it appears in heavy floating mats along margins of ponds, lakes, and even oceans. It is one of the few green algæ ever found in salt water. *Cladophora* is extensively branched (fig. 176), and since its branched filaments are abundantly supplied with chlorophyll, it is clear that this

plant is well fitted for much chlorophyll work, and consequently abundant food manufacture. It grows with remarkable rapidity. A *Cladophora* plant sometimes becomes broken into two or more pieces, when each may grow into a new plant; or at times the cells divide and form many small swimming spores, each of which may grow into a new plant.[1]

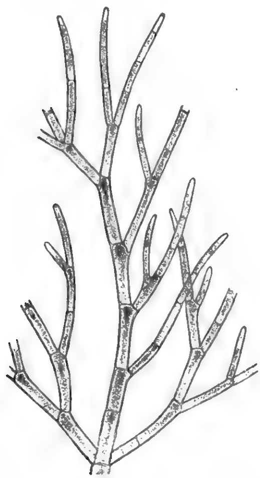

FIG. 176. A branching alga (*Cladophora*)

This plant, but a small part of which is here shown, often forms great mats of growth which cover the rocks and sticks upon which it grows. After Collins

212. *Vaucheria*: habitat and structure. *Vaucheria* is commonly called "green felt," a name which suggests the characteristic appearance which it presents as it grows upon the moist surface of the earth, in pots, on growing tables in the greenhouse, or upon damp, shaded soil out of doors. It also grows in pools of water, where it is distinguished from many other algæ by its coarseness. Certain species of *Cladophora* are coarser than *Vaucheria*, but their greater length and more extensive branching will ordinarily enable one to distinguish them. Plants that have been kept in a dish of water in the laboratory for a few days grow into a heavy, moss-like mass and are good material for study. The plant branches considerably (fig. 177), and the newest branches are the greenest and most active. The older portions may die, thus separating the branches from one another so that new individuals are formed by vegetative reproduction. No cross walls appear in the vegetative part of the plant, and all the cells are within the tubular wall of the plant.[2]

[1] For details of reproduction by spore formation, see *Cladophora* and *Ulothrix* in Bergen and Caldwell, Practical Botany, or Bergen and Davis, Principles of Botany.

[2] Such a plant is called a *cœnocyte*.

213. *Vaucheria:* nutrition. Materials for food-making may be absorbed from the moist earth or from the water in which this plant grows. The abundant chlorophyll suggests considerable ability to manufacture its own nutrient substances, but this plant is not so well fitted for securing abundant exposure to light as is *Cladophora.* It is to be noted that, living on the land as these plants often do, they do not have the protection against extremes of light and temperature that water algæ enjoy.

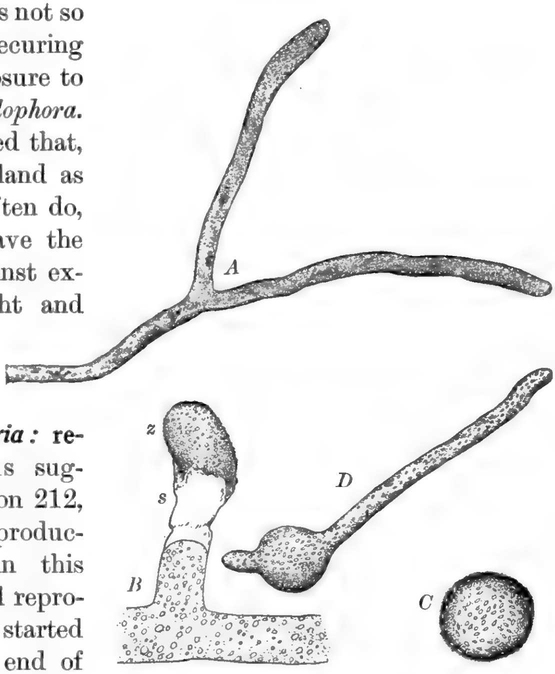

FIG. 177. *Vaucheria*

A, branch of a vegetative plant; *B*, branch forming zoöspore; *z*, young zoöspore just emerging from the sporangium (*s*); *C*, a free zoöspore; *D*, zoöspore germinating to form a new plant

214. *Vaucheria:* reproduction. As suggested in section 212, vegetative reproduction occurs in this plant. Asexual reproduction may be started by having the end of a branch cut off by a cross wall. The part that is thus cut off proceeds to form a large reproductive body (fig. 177, *B*, *C*); the wall which surrounds it breaks, and after a period of swimming it germinates and forms a new plant (fig. 177, *D*). This special reproductive body is called a *zoöspore* (animal spore), or swimming spore. The formation of zoöspores may be induced in the laboratory by keeping *Vaucheria* plants in a dish of shallow water.

Another kind of reproduction may occur at the same time that zoöspores are being formed, though it usually occurs at other times. Upon the sides of the plant special short branches are formed. Two kinds of branches arise near one another (fig. 178). One is short and irregularly spherical, and has a beak. This branch forms one large cell within it. The other branch is longer, somewhat coiled, and has a terminal cell that is cut off by means of a cross wall. In the terminal segment many small cells are formed. Through a small opening in the tip of this coiled branch these cells escape, some of them entering the beak of the other branch and one of them uniting with the large cell. This union forms a spore which proceeds to develop a heavy protecting wall. After a period of rest this spore germinates and produces a new plant.[1]

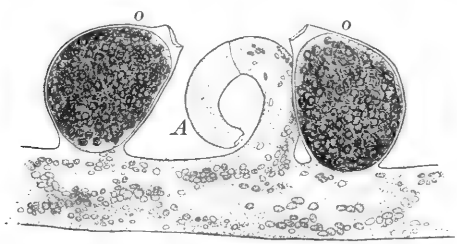

FIG. 178. The sexual reproductive structures of *Vaucheria* (*V. sessilis*)

o, oögonia; *A*, antheridium. Note the opening in the antheridium for exit of sperms, and in the oögonia for their entrance to the large eggs. Greatly enlarged

If this spore had been formed by the union of similar gametes, as in *Spirogyra*, we should have called it a zygospore; but it is formed by the union of gametes that are very unlike, — one large gamete (the *egg*, or *oösphere*) and the other a small gamete (the *sperm*), — and the resulting spore is called an *oöspore*, which means "egg spore." When similar gametes unite to form a zygospore, the process is called *conjugation*, but when dissimilar gametes unite to form an oöspore, the process is called *fertilization*. The special sex organ which produces the sperm is the *antheridium*, or sperm case, and that which produces the egg is the *oögonium*, or egg case.

[1] TO THE TEACHER. No attempt is made to present the difficult and technical questions relative to the alternation of generations in the thallophytes.

Vaucheria has three methods of reproduction — vegetative, by asexual spores (zoöspores), and by sexual spores (oöspores).

One plant may use vegetative reproduction at one period of growth, asexual spore reproduction at another, and sex spore reproduction at another, but two methods are rarely used at the same time.

215. Other green algæ. Although in inland waters green algæ are more abundant than all others, only two other genera will be mentioned in this connection. *Sphærella*, a unicellular form somewhat like *Pleurococcus*, is frequently found in stagnant water. It sometimes grows so luxuriantly in barnyard and roadside pools as to give the water a bright green appearance, and its resting spores may impart a dark red color to drying pools in which the plants have flourished. *Chara*, or stonewort (fig. 179), is a complex alga that is found in great abundance on the bottoms of shallow lakes and streams throughout the continent. It has a heavy coating of calcareous material, which, as the plant dies, falls to the bottom of the pond or stream. *Chara* grows in such luxuriance that its deposits eventually form deep layers of this calcareous material, or marl, as it is called. Marl has been found of great value as one of the materials used in the manufacture of cement, and not a few of the lakes in which *Chara* grows are dredged to secure the marl deposits for this important manufacture.

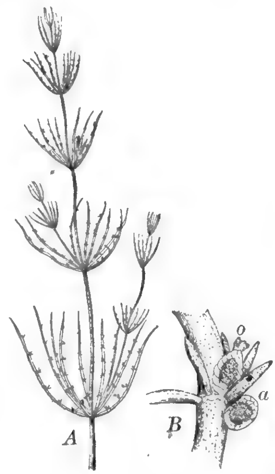

FIG. 179. The stonewort alga (*Chara*)

A, a slightly magnified piece of a plant, showing the general appearance; *B*, a more highly magnified illustration showing the oögonium (*o*) and the antheridium (*a*), by means of which reproduction takes place

216. Algæ and water supply. Many of our large cities have found it advisable to adapt or construct reservoirs for water supply. These are open pools, lakes, tanks, etc., and they are

intended to hold water enough so that there will be a sufficient supply in times of scarcity. Such reservoirs have proved so admirable as growing places for algæ that these plants often become a nuisance. Their presence in water for domestic use is not attractive, and, besides, they may stop up the water pipes. But far more serious than these objections is the actual pollution of the water because of their presence. When they die they become the food for decay-producing organisms, and often positively injurious substances are generated. It has been found that by towing about in such reservoirs a quantity of copper sulphate inclosed in coarse sacking, minute quantities of the salt become dissolved and the algæ are thus killed. The solution is not strong enough to render the water unwholesome for use. This treatment has been an important factor in improving the water in many American cities.[1]

217. The brown algæ. The remaining groups of algæ, though almost exclusively salt-water plants, have such striking characteristics that brief mention of them must be made, and pupils who live near the seacoast will be interested in extending this study. The brown algæ, or brown seaweeds, are found along the shores of all the oceans. They grow attached, by means of strong holdfasts, to rocks, piling, or any relatively fixed support that is available.

From high-tide mark to a little below low-water mark certain brown algæ, known as rockweeds (*Fucus* and *Ascophyllum*) (fig. 180), often form dense coatings upon rocks. At low tide these rockweeds hang loosely over the exposed rocks, and exhibit the characteristic dark olive-green color.

The brown algæ sometimes become detached and are carried hundreds or even thousands of miles from their original

[1] See "A Method of Destroying or Preventing the Growth of Algæ and Certain Pathogenic Bacteria in Water Supplies" and "Copper as an Algicide and Disinfectant in Water Supplies," *Bulletin 64* (1904) and *Bulletin 76* (1905), respectively, Bureau of Plant Industry, U.S. Dept. Agr.; also Whipple, Microscopy of Drinking Water, chap. xii, John Wiley & Sons, New York, 1906.

growing places. This is true in the case of *Sargassum*, some species of which thrive along the shores of tropical oceans. In the North Atlantic Ocean, north of the Canary Islands, is a body of water known as the Sargasso Sea. Its entire area is more or less filled with floating *Sargassum* and other forms of plant and animal life. *Sargassum*, like some other brown algæ, is peculiarly fitted for floating by the presence of "air bladders," which are swollen portions of the leaf-like expansions of the plant. In mid-ocean one may see small floating masses of these plants, which have been carried sometimes hundreds or even thousands of miles from their original homes.

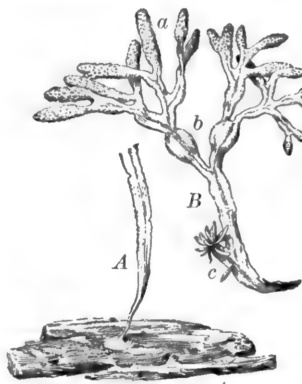

FIG. 180. Rockweed (*Fucus*)

A, the base of a young plant, showing an early stage in formation of the holdfast, which attached the plant to a piece of wood. *B*, tip of a plant; *b*, air bladders; *a*, specialized regions in which reproductive organs are formed; *c*, new leaf-like growth where the plant has been broken. A little less than natural size

218. The kelps. The giant kelps belong to the brown algæ. The cylindrical, stem-like plants sometimes (as in *Macrocystis*) reach a length of from 800 to 900 feet, while "devil's apron," (*Laminaria*) grows into strap-like or widely spread, tough, leathery expansions. All of these forms have heavy, root-like holdfasts, which are so strong that the plant will usually break elsewhere before it will pull away from its support.

At one time the world's supply of iodine was derived from the brown algæ; now it can usually be prepared more economically by chemical means. Soda was formerly secured from these plants, but chemical processes have driven out the laborious methods of securing that substance directly from plants. Gelatinous foods and a sugar known as mannite are secured from some species of brown algæ. In some coastal

portions of this country the farmers collect and carry inland great quantities of brown algæ and spread them over the cultivated land as a fertilizer.[1]

FIG. 181. A red alga (*Dasya*)

219. The red algæ. The red algæ grow mostly in deeper water than do the brown algæ. They are almost wholly confined to salt water.

The marine forms of this group present most striking shapes and colors. They are of different shades of red, varying from the most brilliant to those that are dark and somber, while

[1] For the reproduction of the brown and red algæ, see Bergen and Davis, Principles of Botany.

some are a deep purple. Chlorophyll is present, as in all other algæ, but is often completely obscured by the other colors. Sometimes all the colors are obscured by coatings of calcareous material.

The red algæ have basal holdfasts. The plants are extensively branched (fig. 181) and, as a rule, are smaller and more delicate than the brown forms.[1] The entire plant often looks like a sparsely branched stem with many finely divided leaves. The gelatinous material obtained from certain of the red algæ is by some regarded as a delicacy. In the North Sea and elsewhere in the Atlantic Ocean occurs a red alga known as "Irish moss," which is collected in large quantities and employed in the preparation of jelly, to be used both directly as food and as a basis for the preparation of other foods.

PROBLEMS

1. Why are the blue-green algæ on the whole considered to be of lower organization than the green algæ?

2. Which of these groups is more injurious in its effect on reservoirs of drinking water? Why?

3. Why is it often found desirable to build roofs over such reservoirs?

4. In what ways do algæ help or hinder the life of aquatic animals? How does an aquarium aid in answering this question? What bearing on it has the fact that the flinty cell coverings of some of the microscopic algæ (diatoms) are found in the digestive cavities of oysters?

5. What algæ are used as human food?

6. May polishing powders or pastes be made of fossil remains of algæ? Use a compound microscope in examining some such powders.

7. It is generally supposed that algæ were among the first plants to appear on the earth in very early geological times. Does this seem probable?

8. How do the algæ pass through the winter and seasons of drought?

[1] The best way for the teacher to give a general notion of brown and red algæ is to secure card mounts or bottled material for class demonstrations of a few of the leading types in each group. These may be obtained from the Woods Hole Biological Laboratory, Woods Hole, Massachusetts, and from other reliable supply houses. Well-prepared card mounts preserve the natural colors, and may be kept indefinitely for laboratory use.

CHAPTER XVI

FUNGI AND FUNGOUS DISEASES OF PLANTS

220. The fungi as dependent plants. In our earlier discussion of plant nutrition it was found that green plants possess chlorophyll, by means of which they make their own foods. Every observant person who has had any considerable experience with plants has noted several or many kinds, as mushrooms and molds, that do not possess chlorophyll. These chlorophyll-less plants cannot manufacture foods from water and carbon dioxide, and hence are dependent. Their dependence appears in various relations between them and the host plants or animals that supply them the requisite food. Sometimes they live upon or within living plants or animals, being known as *parasites*; or they may live upon dead nutrient substances, when they are known as *saprophytes* (fig. 182).

FIG. 182. An old pine stump upon which the fungus *Polyporus* is growing

There are many common fungous parasites, as wheat rust, potato blight, and tree-destroying fungi. Our economic crops are greatly reduced in value every year through the destructiveness of these parasitic plants. Fungous saprophytes are also very abundant, the best-known being molds, mushrooms, and puffballs. In almost any deeply shaded, moist, and warm

undergrowth one may find large numbers of these saprophytic plants growing upon decaying organic matter. By breaking open an old log or branch of wood (fig. 183) upon which fungi are growing, or by upturning rich soil, one often finds the extensively interwoven, mold-like saprophytic growth. This internal growth gathers nourishing material for the whole dependent plant, and at the same time helps to bring about the decay of the material upon which it lives.

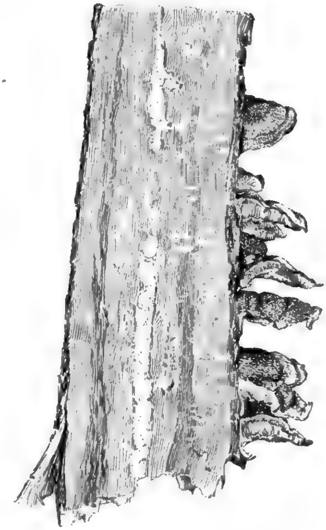

FIG. 183. A section through a dead branch of a cottonwood tree

Note the white patches of internal mycelium and the external spore-producing bodies of the fungus, a *Polyporus*

221. The algæ-fungi. There are many different groups of fungi, and they are often so unlike that it is at first hard for the student to regard them as belonging to the same larger group, the fungi. In the case of some of the molds, if the thread-like fibers of which they are composed were to possess chlorophyll, they would appear quite similar to some of the algæ. Because of this structural resemblance one group of fungi is called the algæ-fungi (*Phycomycetes*, meaning "algæ-fungi"), that is, fungi that are more like algæ than are other fungi. Most of the saprophytic molds and a good many destructive parasites belong to the algae-fungi. A few types will show their nature, how they live, and how they affect the things upon which they live.

222. Bread mold. If a piece of slightly moistened bread is placed in a glass jar or in a covered dish for a few days, an abundant supply of mold soon appears upon it. Several kinds of molds may develop at the same time under such conditions, but the common bread mold, or black mold, is the one which

usually appears. It grows in and about our homes in great abundance, upon bread, fruits, and other favorable nutrient substances that are left exposed. When young the mold is white, only assuming its blackish appearance when spores are formed.

223. Vegetative structures, and nutrition of bread mold. A mass of growing bread mold is composed of many white threads grown together until they have become closely interwoven. Each thread is called a *hypha* ("a single web"), and the whole network of hyphæ is the *mycelium*, or fungus mass.

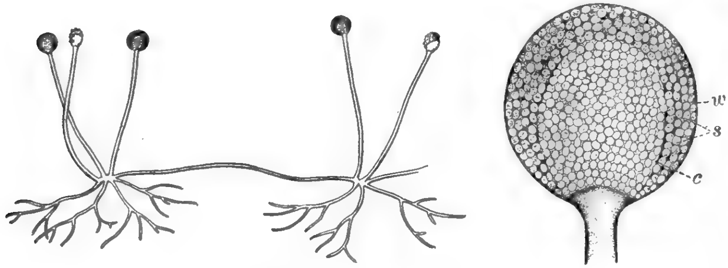

FIG. 184. Bread mold

At the left is a slightly magnified illustration of plants, one of which has given rise to the other by means of a runner, or stolon. Descending are the rhizoids and ascending are the aërial branches, upon the tips of which spores are borne within sporangia. At the right a more highly magnified sporangium is shown. Its wall (w) incloses many spores (s), through which may be seen the columella (c), which is the swollen tip of the stalk upon which the sporangium is borne. This wall may be broken away, so as to leave some of the spores lying upon the columella, as is seen in two cases of the plants shown at the left

Careful examination also shows that some of the hyphæ have grown down into the bread, and if one could see through the bread after mold has grown on it for a few days, much of the mycelium would be seen within it. Branching downward from some of the superficial hyphæ are special root-like hyphæ (*rhizoids*) (fig. 184), which descend and spread within the nutrient material. At such places upright hyphæ also are formed. Long, runner-like branches (*stolons*) may extend over the surface a little way. From the stolons a new set of rhizoids and upright hyphæ may grow.

Under magnification the hyphæ may be seen to consist of heavy, tubular cell walls, in which the granular protoplasm is not separated into distinct cellular divisions by transverse walls, as it is in most of the algæ.

Bread mold lives upon and within its nutrient substance and absorbs food material directly from it. Parts that are in contact with the sub-stratum do the work of food absorption. Food is carried through the tubular cells to the parts of the mycelium that are above the food material. Since nutrient material is secured in ready and abundant supplies, the growth and extension of the mold is usually quite rapid.

224. Effect of mold upon bread. If a piece of bread upon which mold is growing vigorously is kept moist, much of the bread is consumed by the mold, but usually the mold will not continue to grow until the bread is completely consumed. Either because it has secured all the food it can extract from the bread, or because it has secreted substances that prevent its further growth, or because it is unable to hold its own with other organisms (molds and bacteria), the bread mold after a time ceases to grow. Other molds and bacteria may appear, one kind following another for weeks, until the decay of the bread is almost or quite complete.

If the mold, and the material upon which it grows, is kept tightly sealed, growth stops before all the food material is used. Molds often grow for a time in jars of fruit, forming upon the top of the fruit a coating which remains until the jar is opened. If this coating is removed and a fresh supply of air is admitted, a new growth soon appears, and if a constant supply of air is maintained, various molds may grow until all the fruit is destroyed.

225. Reproduction of bread mold. In addition to vegetative reproduction by means of stolons, this mold also reproduces itself both asexually and sexually. Upon the ends of upright hyphæ, sporangia are produced (fig. 184). In the development of the sporangia, first a transverse wall cuts off a small tip of the upright stalk. This tip cell grows rapidly until it

has become a large, spherical body. Meanwhile the transverse wall has extended into the spherical sporangium, thus producing a little column (the *columella*), upon which the sporangium contents rest. The protoplasm of the sporangium divides into many small spores, which, when the sporangium wall breaks, are scattered widely into the air. The musty odor which is detected when we smell mold may be due to the presence of large numbers of these spores or to gases that have been produced within the nutrient material.

FIG. 185. Grape leaf with grape mildew

A leaf of the grape, upon which may be seen the white, fluffy patches of grape mildew. Photograph by H. H. Whetzel

If bread that has not been exposed to the air is cut in a room in which the air is quiet, and if one piece is covered directly in a glass dish, another similarly covered after five minutes' exposure to the air of the room, and another after five minutes' exposure on the outside window sill, an interesting test of the abundance of spores in the atmosphere will be afforded. One class of students, in performing this experiment, secured the development of mold upon all three pieces of bread, having in all five kinds of mold. Another class used sterilized gelatin culture material and exposed it to the air of a schoolhouse hallway for five minutes, and during the following week there grew upon the gelatin eight different kinds of molds and bacteria. Juices of fruits, as prunes, are also good nutrient materials for experiments in growing molds.

In addition to reproduction by asexual spores, sexual reproduction sometimes occurs. Tips of branches unite and form heavy-walled zygospores, somewhat after the manner of zygospore formation in *Spirogyra*.

226. The grape downy mildew. It is not uncommon to see the white patches of downy mildew upon the leaves of the grape (fig. 185), and sometimes it appears upon the green shoots and the fruit. In the central states, supposed to be the original home of this parasite, it has been an injurious pest for many years. In some localities it well-nigh destroys the grape crop at times, but when conditions are thoroughly favorable to the vigorous growth of grape plants, the mildew does not seriously interfere with the crop of grapes. When plants which are attacked by the parasite are properly sprayed, the ill effects may be reduced or prevented. The spray kills spores which are upon the leaf's surface.

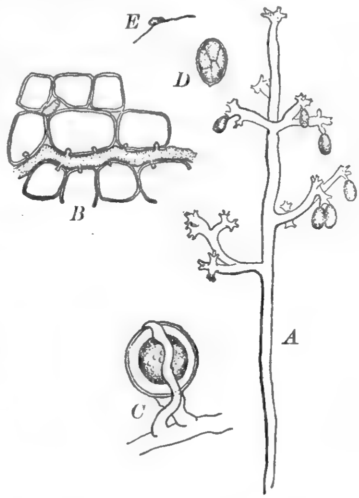

FIG. 186. Grape mildew (*Plasmopara*)

From the mycelium within the cells of the grape leaf, haustoria (*B*) are formed. Upright hyphæ (*A*) bear conidia. These conidia divide, as at *D*, and form zoöspores (*E*). Within the leaf, oöspores (*C*) are formed. After Duggar

227. Structure and nutrition of grape mildew. The surface patches that are characteristic of downy mildew are not produced until some time after the leaves have had the parasite growing within them. The threads, or hyphæ, grow between the cells of the leaf, and through the walls of these cells there grow short branches (*haustoria*), which absorb food directly from the cell contents of the host plant (fig. 186, *B*). Thus the parasite may grow by means of the food material made

by the grape leaf, until the fungus permeates the entire leaf. If the leaf is not able to make a surplus of food material, the amount taken by the parasite may result in the starvation and death of the grape leaf. Possibly, also, the parasite may excrete substances that poison the host plant.

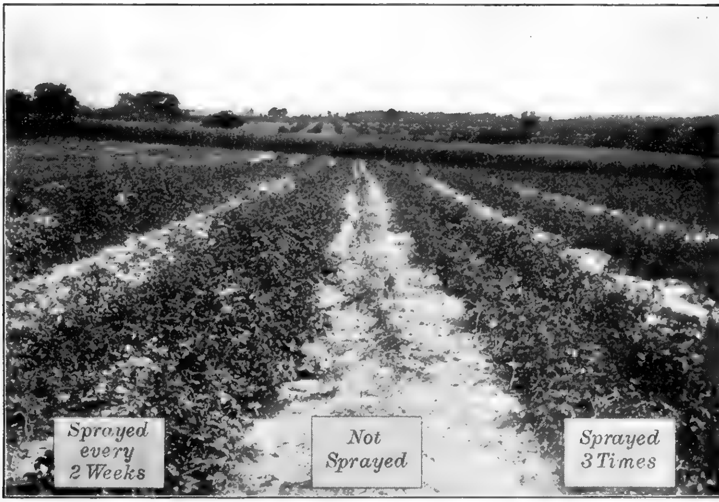

FIG. 187. Experiments in destroying potato blight

Photograph by the New York Agricultural Experiment Station illustrating the results of spraying potatoes to prevent disease. Those that were not sprayed yielded at the rate of 161 bushels per acre; those sprayed three times during the season yielded at the rate of 350½ bushels per acre; those sprayed every two weeks yielded at the rate of 380 bushels per acre. In other experiments the results are even better. In this same station, during the year 1904, the average gain per acre in the yield for three sprayings is 191 bushels, and the gain for spraying every two weeks is 233 bushels

228. Reproduction of grape mildew. Sometimes the upright branches of aërial hyphæ of grape mildew produce rounded, spore-like bodies (*conidia*) (fig. 186, *A*). When these conidia come into favorable moisture (rain or dew) and temperature, they divide, each one forming several zoöspores (fig. 186, *E*). The conidia, therefore, act like sporangia, since they form asexual spores. The zoöspore may swim in the dew or rain for

fifteen or twenty minutes, and then lose its cilia and begin to grow into a new hypha of the mildew. These new hyphæ may grow through the stomata of leaves and start a new growth of the parasite.

Within the host leaf sexual reproduction of the parasite occurs, and oöspores (fig. 186, *C*) are formed. These oöspores are thought to reproduce the parasite in the following spring, when the decay of the host leaf releases them. Our knowledge of oöspore formation in grape mildew and potato blight is still incomplete. It is thought, however, by some special students of fungi, that potato blight has largely lost its power of sexual reproduction, and that oöspores are not often formed.[1]

229. Prevention of grape mildew and potato blight. Potato blight is a common and extremely destructive potato disease caused by a fungus that resembles grape mildew in its structure and habits of growth. It is readily and widely distributed and often causes serious losses by partially or almost completely preventing the growth of a potato crop. Both potato blight and grape mildew are prevented from reaching their normal growth, and are sometimes completely destroyed, by spraying with Bordeaux mixture.[2] It was in connection with a study of grape mildew that the Frenchman Millardet, in 1881, began experimenting with Bordeaux mixtures. He demonstrated the fact that this mixture, when properly used as a spray, will prevent most of the ill effects of grape mildew. The effect of using this spray in treating potatoes is well shown in figure 187. Many other destructive parasitic diseases of plants, though by no means all of them, may be prevented in the same way.[3]

[1] G. P. Clinton, "Oöspores of Potato Blight," *Science*, 744–747, 1911.

[2] The preparation as most commonly used consists of materials mixed in the following proportions : copper sulphate, 5 pounds ; stone lime, 5 pounds ; water, 50 gallons. Other proportions are often used, as indicated in agricultural experiment station reports.

[3] Duggar, B. M., Fungous Diseases of Plants. Ginn and Company, Boston, 1909.

"Potato Spraying Experiments in 1906," *Bulletin 279*, N.Y. Agr. Exp. Sta.

"Certain Potato Diseases and their Remedies," *Bulletin 72*, Vt. Agr. Exp. Sta.

Among the other algæ-fungi which cause common destructive diseases are those which cause the cranberry gall; the brown rot of lemons and other citrous fruits; the white, or downy, mildew of shepherd's-purse, the common radish, mustard, and turnip; and the downy mildew of cucumbers, pumpkins, watermelons, and lima beans.

230. The sac fungi. Some of the more common sac fungi are the cup fungi, the morel, the yeasts, and the mildews; the latter often appear upon leaves of plantain, smartweed, lilac,

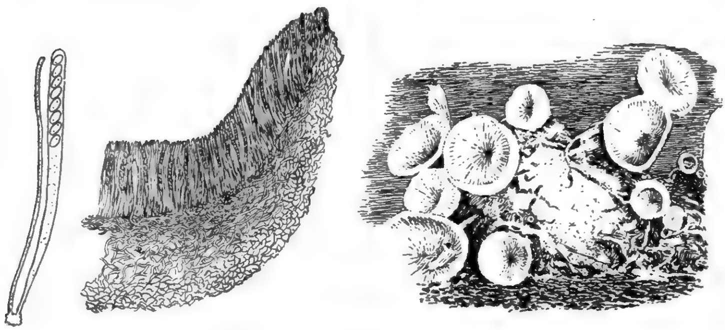

FIG. 188. Brown rot (*Sclerotinia*) growing upon old plums

At the right are some of the fruiting cups; in the middle is a greatly magnified portion of the cup, showing the spore-bearing areas; and at the left is one of the spore-bearing threads still more magnified, so as to show the spores. After Duggar

and oak. More fungi belong to this group than to any other, and since most of them are parasitic, it is evident that they are of great economic importance. They have wide variations in form and structure. Usually the parasitic sac fungi grow upon instead of within the host plant. From this superficial growth haustoria are sent into the tissues of the host plant.

As illustrations of the damage that may be done by members of this group we may cite the brown rot of peaches, plums, cherries, and apricots. Old dried fruits are sometimes found lying on the ground or still clinging to the trees. These "mummies" are a result of the brown rot. Sometimes they produce little brownish cups which are the spore-producing

structures of the plant (fig. 188). Most of the damage is done to the fruit before any of these cups appear; indeed, the fruit is worthless before the parasite has matured. Spores are distributed from the cups and new infection of fruit occurs, and thus the destruction is continued. The spores are formed within the tissues of the cup in the enlarged ends of hyphæ, and these enlarged spore-forming tips of the hyphæ are the sacs from which the group name *sac fungi* is derived. The sac is called the *ascus* (sac), and the group of plants is called the *Ascomycetes* (sac fungi).


Fig. 189. A group of morel mushrooms

Brown rot seems to attack all kinds of stone fruits, and the total amount of damage done by it is enormous. In 1887 it was reported that the disease had caused a shortage of 800,000 baskets in the peach crop of Maryland and Delaware for that year. In 1900 Georgia lost about 40 per cent of its peach crop—a money loss of between $500,000 and $700,000.[1]

The disease may be checked by destroying the infected fruits and twigs. Spores are so generally distributed that spraying is also necessary. Different sprays have been used, but with such varying success that the advice of local experiment stations should be sought for the special needs in each state.

231. The morel. Another representative of the sac fungi is the morel mushroom (*Morchella*) (fig. 189). Its mycelium grows in earth that is very rich with decaying organic matter. It is usually found in woods, among the leaves and about old logs and stumps. The mushroom is the only part usually noticed, and under favorable conditions of moisture and

[1] "The Brown Rot of Peaches, Plums, and Other Fruits," *Bulletin 50*, Georgia Agr. Exp. Sta., 1900.

temperature it develops in a very short time, growing by means of food material that has been gathered by the underground growth. In the deep, wrinkle-bordered pits of the mushroom are the spore-bearing hyphæ. The spores form in great numbers; they are very light and are easily carried long distances by currents of air. Most of the mushrooms do not belong to the *Ascomycetes*.

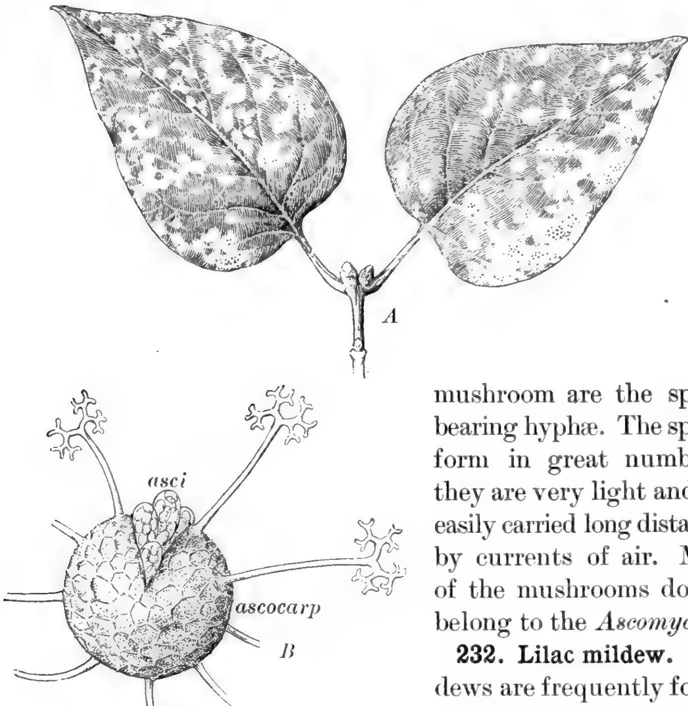

FIG. 190. Lilac mildew

A, leaves of lilac upon which lilac mildew appears in whitish patches; the small, dark reproductive bodies are also shown. *B*, the central, heavy-walled body (ascocarp) which contains the sacs (asci) in which spores are formed. Upon the wall of the ascocarp are stalks, sometimes called arms, which have peculiar branches at their tips. About 60 times natural size

232. Lilac mildew. Mildews are frequently found upon the surface of leaves of lilac (fig. 190) and upon the willow, oak, some of the smartweeds, and many other plants. The fungus is a superficial parasite with haustoria penetrating the host cells.

At times upright hyphæ form conidia, and to their presence the powdery appearance of these mildews is largely due. The conidia, if favorably placed, are the means of producing new

growths of the mildew. Another complex method of reproduction results in forming a heavy-walled body, the *ascocarp*, so called because it is the body which contains the sacs and ascospores (fig. 190). In late summer the ascocarps may, without magnification, be seen as small black bodies upon the surface of lilac leaves. When the ascocarp is broken, the sacs and spores are exposed. From the walls of the ascocarp peculiar arms extend, and in the lilac mildew and some related mildews these have strikingly branched tips.

The heavy-walled ascocarp is resistant to unfavorable climatic conditions. It may pass through the winter and break open in the following spring, thus freeing the thin-walled sacs. Upon escaping from the sacs the spores may be blown or carried about and germinate upon new host leaves.

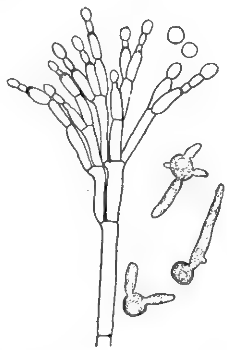

FIG. 191. The blue mold

At the left is the tip of a hypha, with the characteristic branches, on the ends of which are the spores; at the right are germinating spores. Much magnified. After Thom

233. Blue mold or green mold. When old shoes, gloves, or other articles made of leather are left in damp, warm places, a blue or green mold (*Penicillium*) frequently develops upon them. This mold also grows upon old lemons and oranges, and upon cheese. Various species have distinctive shades of color, so that the common names of *blue mold* or *green mold* can be taken only as applying in a general way. Certain species of *Penicillium* are said to give characteristic flavors to the cheese in which they grow, as *Penicillium Roqueforti* of Roquefort cheese and *Penicillium Camemberti* of Camembert cheese. These species are widely distributed and are found growing upon many substances besides cheese.[1] *Penicillium*

[1] An interesting discussion of various species and their cultural reactions is "Cultural Studies of Species of *Penicillium*," by Charles Thom, Ph.D., Mycologist in Cheese Investigations, *Bulletin 148*, Bureau of Animal Industry, U.S. Dept. Agr., 1910.

is a sac fungus which has almost lost the habit of reproduction by means of ascospores, the sac being rarely formed. It reproduces itself very abundantly by means of conidia (fig. 191). The number of these conidia is often so large that when the substance supporting the plants is slightly shaken, a small cloud of spores arises.

234. Yeasts. The yeasts constitute a group of plants of somewhat doubtful classification. Since they occasionally form sacs in which spores are formed, they are often classed with the sac fungi. They are extremely simple, and are more interesting because of their manner of life than because of their structure. A yeast plant is a single cell (fig. 192). It usually reproduces itself by a method of vegetative reproduction known as *budding*. The buds, before becoming separated from the parent cells, may bud again and again until a chain of plants is formed. If a cake of commercial yeast is examined, it is found, in addition to the large starch grains nearly always occurring in yeast cakes, to consist of hundreds of thousands of yeast cells, some single and some in process of budding. If a cake of yeast is kept at room temperature, the plants soon continue their growth, and other organisms (bacteria and molds) also grow, so that the yeast "spoils."

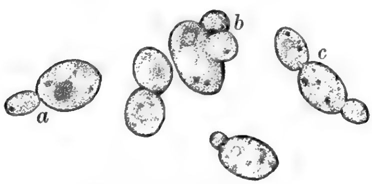

Fig. 192. Yeast plants

a, a plant from which a bud has begun to grow; *b* and *c*, plants with two buds. Note the vacuoles in the plants. Greatly enlarged

When yeast plants are placed in dough, they grow with great rapidity. They live upon the solutions in the dough, and in so doing they break down the sugar, thus forming from it small quantities of alcohol and carbon dioxide. The carbon-dioxide gas forms air spaces which cause the phenomenon known as *rising*.[1] During the process of baking, the air spaces

[1] Salt-rising bread owes its peculiar quality to the fact that, instead of yeasts, certain bacteria produce fermentation within the dough.

are enlarged, and at the same time the alcohol is evaporated. By former methods of bread-making pure cultures of yeast were less likely to be secured, wild yeasts very frequently appearing. By modern methods, quite similar to those used in bacteriology, pure cultures may be obtained, and it is therefore possible to secure the exact kind of fermentation of the dough that is desired.[1]

The processes of fermentation by yeasts are used in the manufacture of alcohol, wine, beer, and other liquors which contain alcohol. Certain definite kinds of yeast produce certain kinds of alcoholic fermentation, and it is necessary for the brewer to keep pure cultures of the desired yeasts in order to insure the particular quality of his product. In 1856 the great French scientist, Louis Pasteur, succeeded in devising methods of pure culture by isolating single yeast plants and growing a colony from each. Thus the particular result to be secured could be determined by the kind of yeast selected for use in fermentation. It was this method of pure culture which opened the way for many of the modern bacteriological investigations.[2]

235. The lichens. This is a group of plants of peculiar habits and structures. Often members of the group may be seen adhering closely to the bark of trees (fig. 193) or to the surface of rocks. They also appear upon the soil in great abundance. Sometimes they hang from branches of trees in ragged gray masses (fig. 194) that look somewhat like the common Southern hanging seed plant known as Florida moss.

[1] An especially interesting paper is "Bread and the Principles of Bread Making," by Helen W. Atwater, *Farmers' Bulletin 112*, U.S. Dept. Agr., 1910.

[2] The following citations will indicate a few of the many plant diseases that are caused by sac fungi.

"Root Rot of Tobacco," Annual Report, Conn. Agr. Exp. Sta., 1906.

"Peach Mildew," *Bulletin 107*, Colo. Agr. Exp. Sta., 1906.

"Wilt Disease of Cotton, Watermelon, and Cowpea," *Bulletin 17*, Division of Vegetable Pathology, U.S. Dept. Agr., 1899.

"Black Knot," *Bulletin 81*, Cornell University Agr. Exp. Sta., 1894.

"The Bitter Rot of Apples," *Bulletin 44*, Bureau of Plant Industry, U.S. Dept. Agr., 1903.

Although usually grayish green in color, some of the lichens are yellow, red, brown, or even black. Lichens can endure severe drought, cold, and prolonged exposure to intense light and to strong winds; hence it is evident that they can live under conditions which would be destructive to most kinds of plants. On account of this ability to undergo severe conditions, lichens are found at as great altitudes and throughout as great a range north and south as are any plants. They may remain dormant through long periods of unfavorable weather and, when favorable moisture and temperature return, almost immediately assume the greenish appearance which indicates their renewed activity. The lichen known as reindeer moss is brittle and pallid when dry, but when moist, it is green and soft.

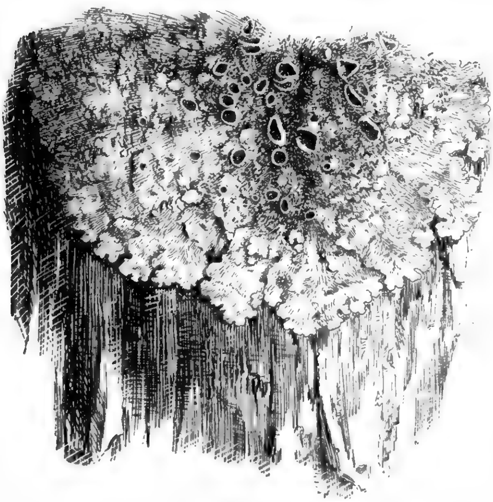

FIG. 193. A common lichen (*Parmelia*) upon the bark of the shagbark hickory

Note the expanded and flat part of the lichen, also the cups in which spores of the fungus part of the lichen are formed

Those lichens which adhere very closely to their support and are scale-like are called *crustaceous;* those that adhere less closely and are leaf-like are *foliose;* and those that branch and are partially free from their sub-stratum are *fruticose.* Foliose forms are common upon rougher-barked trees and upon old fences, crustaceous forms grow upon smooth-barked trees and upon stones, while fruticose forms grow upon the ground or hang from branches of trees.

236. The structure of a lichen. A lichen is not a single plant, but a combination of fungi and algæ living together in such a close relationship that it looks like a single plant. There may be many individual fungi and many individual algæ in this relation, but the combination is spoken of as the lichen plant. The fungal part of the lichen is usually, though not always, a member of the sac-bearing class of fungi, and

FIG. 194. The "bearded moss" lichen (*Usnea barbata*) growing upon the branches of a spruce tree

consequently ~~lichens are often~~ classified with sac fungi. This is obviously a somewhat questionable classification, but for lack of a better one we shall use it. The algæ that enter into the formation of lichens are usually unicellular forms resembling *Pleurococcus*. When the lichen is dissected, the green cells of the algæ and the white threads of the fungi may be seen (fig. 195). The chlorophyll of the algæ enables the lichen to manufacture carbohydrate foods. Individual alga cells are often closely wound about by threads of the fungus;

these threads absorb food from the algæ. The fungus seems to hold the combination in compact form and to enable it to secure a foothold in places where neither the alga nor the fungus could live alone. In the lichen we have therefore a combination of plants — an alga and a fungus — neither of which alone could live long under the conditions of extreme exposure in which lichens are often found.

237. Economic significance of lichens. As lichens live in exposed rocky places, they serve to bring about the first stages of soil formation by the decay of old lichen plants and by the breaking up of the surface layers of the rock or other material

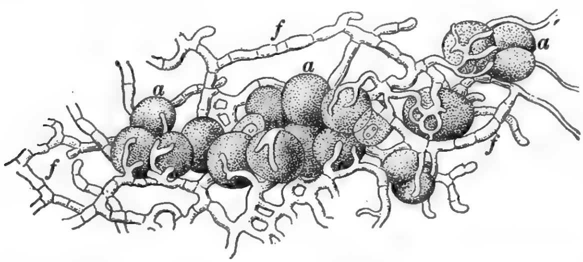

FIG. 195. A small piece of the interior of a lichen, showing the relation of the alga (*a*) and the fungus (*f*)

Magnified 500 diameters. After Bonnier

upon which they grow. Weathering processes also assist in crumbling the rock, and after a time there is soil enough to permit the growth of larger plants. Several kinds of crustaceous lichens are usually the forerunners of other vegetation in rocky regions which will not permit other forms of vegetation to live. The time required to produce enough soil for the growth of other plants depends largely upon the nature of the rock and the climate. It is said that on some lava beds, after almost two hundred years from their formation, crustaceous lichens are still in some places the only plants to be found. Lichens are important as food for herbivorous animals in regions where other kinds of food are scarce or where for a part of the year other vegetation is not available.

Reindeer moss (*Cladonia rangiferina*) is eaten in winter by animals, which find it green and nutritious when they remove the snow from above it. A few lichens are used as food for men, though they are not especially nutritious. A mucilaginous and starchy food is prepared from *Cetraria islandica*, a lichen which is known as Iceland moss. In Sweden *Sticta pulmonacea*, a very bitter lichen, is sometimes used as a substitute for hops in processes of brewing. Various dyes are prepared from lichens and are known in the markets as *orchil* and *cudbear*, but these are not so commonly used as formerly. *Litmus*, used in preparing litmus, or blue-test paper as a test for the presence of acids, is also prepared from lichens.

FIG. 196. Corn smut

An ear of corn, part of which has been destroyed and replaced by a mass of smut spores. Photograph by Kern, Pennsylvania State College

238. The basidium, or stalk fungi. The sac fungi were so named because the spores are formed in a sac. In like manner the basidium, or stalk, fungi (*Basidiomycetes*) are so called because the spores are formed on the outside of the tip of a hypha known as the stalk, or basidium. Within this division of fungi several sub-divisions are recognized. One of these, the *smuts*, is represented by forms that frequently appear upon the ears of corn (fig. 196) and upon heads of oats (fig. 197), wheat, barley, and other

members of the grass family; another sub-division is the *rusts*, found wherever wheat and oats are grown, and also appearing upon many other host plants; *mushrooms* and *puffballs*, another sub-division, are widely distributed wherever there is a good supply of decaying organic matter, and some grow as parasites upon living trees. Because of the frequency of the parasitic habit in the stalk fungi, it is evident that the group is one of great importance to industries that depend upon the growth of plants.

FIG. 197. Smut on the oat plant

Two heads of oats, each with the leaf (*l*) which sheathes the stalk. The head at the left has matured its grains in a normal manner, while in the one at the right the grains are supplanted by the blackened masses of the smut. One third natural size

239. Damage from smuts. The cereals are particularly affected by these parasites, since all of the smuts are parasitic and since the grains seem to be especially favorable hosts for them. Different writers present very different estimates of the amount of damage done to our crops annually by these parasites, but a conservative estimate made by the United States Department of Agriculture states that the loss from smut in wheat, oats, and barley exceeds $25,000,000 annually, and that the loss in oats alone exceeds $6,500,000. The damage to corn is probably about equal to that of oats. Some writers estimate the loss to our crops as several times greater than the above conservative estimates. Whatever may be the exact loss, it is evident that the matter is one of great significance.

240. Corn smut. This smut (*Ustilago maydis*) is ordinarily first noticed when it forms whitish masses in the ear or tassel or upon other parts of the corn plant. These masses develop into spores and become black, sticky, and unsightly. But

before the smut appears on the surface, its mycelium grows more or less throughout the corn plant. Every part of the host may be infested by the mycelium, which grows wholly by means of food material derived from the host. In addition to this food tax levied upon the host by the parasite, the corn grains and tassels are often occupied and eventually destroyed by the smut. Finally the spores may fall to the ground and, after a period of dormancy, germinate and produce a short hypha, which bears spores that may serve to infect the next crop of corn with the parasite.[1]

241. Oat smut. The behavior of this parasitic plant (*Ustilago avenae*) (fig. 197) is similar to that of corn smut. The ripened spores may lie upon the ground, adhere to the grains, or remain upon the straw until there are favorable conditions for growth. Probably the grain used for seed is one of the chief means of spore distribution. It has been found that by treating seed oats for a brief period with hot water (132° to 133° F.) or with water containing $\frac{4}{10}$ per cent formalin the smut may be killed.

It is possible for both corn and oats to mature grain even while infected with smut, but usually partial or total destruction of the grains results. Some kinds of corn and oats seem to be more resistant than others to attacks from the disease. The importance of preventing the growth of smut by treatment of seed oats and corn and by a search for resistant varieties of oats and corn is evident.

242. The rust fungi. The rusts are among the most widely distributed and most destructive plant parasites. Many kinds of plants are susceptible to attacks from rusts. Indeed, a given kind of rust may live for a time upon one kind of host plant and later upon another kind. In each stage the rust presents a different appearance; because of this, in earlier studies

[1] "Corn Smut," Ind. Agr. Exp. Sta., 1900.
"The Smut of Grain Crops," *Bulletin 122*, Minn. Agr. Exp. Sta., 1911.
"The Smuts of Wheat, Oats, Barley, and Corn," *Farmers' Bulletin 507*, U.S. Dept. Agr., 1912.

of these plants the different stages were thought to be different plants, and were so named. For example, the rust that develops on leaves of the apple tree early in the spring forms spores. These spores produce the parasite known as cedar apple (*Gymnosporangium*), which grows upon cedar trees. Each stage produces spores which, after germinating in favorable places, produce the other stage of the rust.[1]

Wheat and oat rust is probably the best-known and most-feared member of the rust sub-division of fungi. In the United States it does damage to our wheat and oat crops every year to the amount of at least $15,000,000, and probably much more.

The first conspicuous appearance of rust in the late spring or early summer is in the form of reddish-brown patches upon stalks and leaves of wheat and oats (fig. 198). The patches are composed of large numbers of summer spores (*uredospores*). A section cut through the host leaf enables one to see that the summer spores (fig. 198, *B*) are formed upon the ends of hyphæ. The spore-bearing ends of hyphæ are continuations of hyphæ which have pushed their way among the leaf cells from which they have absorbed their nourishment. At the time summer spores are formed, the host plant is usually thoroughly infested with the mycelium. The summer spores are readily carried about by currents of air or by contact with animals. If placed upon wheat or oat plants, these spores germinate (fig. 198, *C*) and the young hyphæ penetrate the host and produce new mycelium.

Later in the summer the same mycelium which produced summer spores produces a heavy-walled, two-celled spore (fig. 198, *D*) known as the winter spore (*teleutospore*). When formed in large quantities, these spores appear as blistery patches much like those made by the reddish summer spores, except for the difference in color. The winter spores are scattered over the ground and upon wheat and oat straw. After

[1] "The Cedar-Apple Fungi and Apple Rust in Iowa," *Bulletin 84*, Iowa Agr. Exp. Sta., 1905.

"The Asparagus Rust: its Treatment and Natural Enemies," *Bulletin 129*, N. J. Agr. Exp. Sta., 1898.

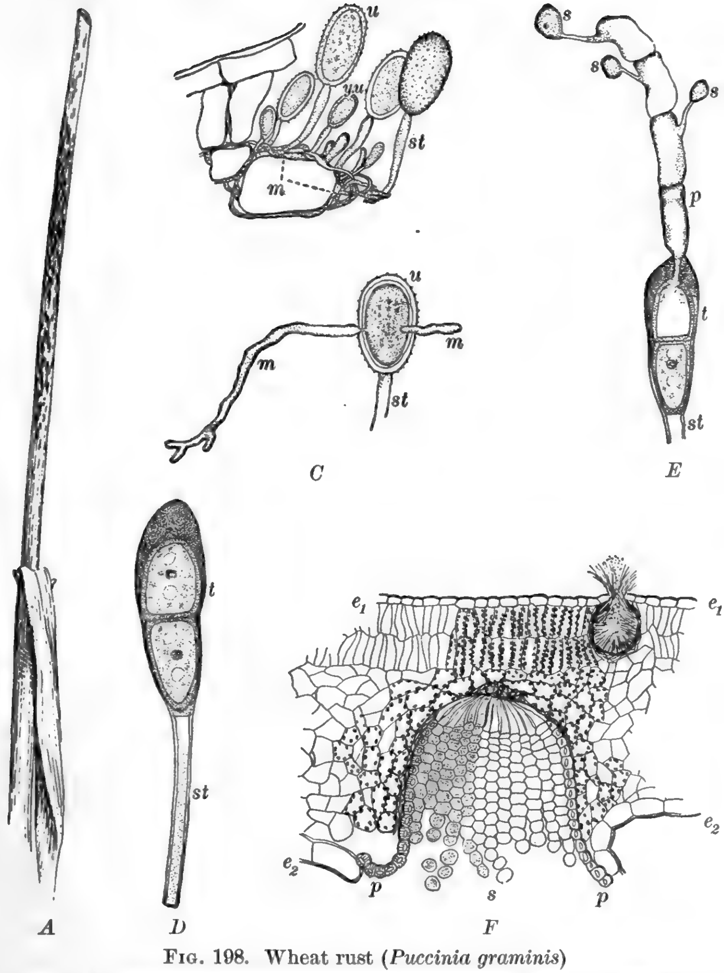

Fig. 198. Wheat rust (*Puccinia graminis*)

A, part of a wheat plant showing rust spots on the stalk. *B*, a small section of a wheat leaf upon which the parasitic rust is growing: *m*, mycelial hyphæ of the rust; *y.u*, young summer spore, or uredospore; *u*, fully formed uredospore; *st*, upright hypha upon which uredospore is formed. *C*, germination of uredospore: *st*, old hypha; *u*, old uredospore wall; *m*, new mycelial hyphæ. *D*, winter spore, or teleutospore: *st*, hypha; *t*, two-celled spore. *E*, germination of teleutospore (*t*): *st*, old hypha; *p*, new hypha, or the promycelium; *s*, spores, or sporidia. *F*, section of the barberry leaf, showing æcidiospore stage of rust: e_1 upper epidermis, and e_2 lower epidermis; *p*, wall of cup, or æcidium; *s*, æcidiospores. All much enlarged. Rearranged from Duggar's "Fungous Diseases of Plants"

a period of dormancy, usually lasting through the winter, these spores germinate. From each cell of the winter spores in the spring there grows a small hypha (fig. 198, *E*). Each cell of this hypha forms one thin-walled spore (*sporidium*).

This rust (*Puccinia graminis*) has another stage in its life cycle. The sporidia, when alighting upon leaves of a shrubby plant known as the barberry, grows and produces within the leaf an extensive growth of mycelium. When this mycelium produces spores, they appear in a peculiar cup on the underside of the barberry leaf (fig. 198, *F*). These spores, being different from any of the three described, and being formed in a cup, are called *cup spores.* Cup spores reproduce the rust plant upon wheat and oats. Summer spores persist through the winter, and it is thought that they also reproduce the rust upon oats and wheat in the following spring. No satisfactory preventive for this fungus has been discovered. Some progress has been made by learning which varieties of wheat and oats are most resistant to attacks by the parasite.[1]

243. Mushrooms. In this sub-division of stalk fungi those members that are good to eat have been popularly called mushrooms, while those not edible were called toadstools. Scientifically there is no accepted distinction of any kind, and the name *mushroom* is now being used for the whole group. In a given genus some species may be edible, others not. Also, some species are edible while young, but not so when older. Some of the more common edible species are easily learned and not readily confused with poisonous forms. In the United States over one thousand edible forms are known, but some of them are very rare.

244. The general character of mushrooms. The mycelium of mushrooms lives entirely within the material which furnishes its nourishment, and from this mycelium it may send up into the air the spore-bearing structure commonly regarded as the entire mushroom. The mycelium becomes very extensive and forms moldy or cobweb-like threads within the rich

[1] "Rusts of Cereals," *Bulletin 109*, S.Dak. Agr. Exp. Sta., 1908.

earth, decaying wood (fig. 183), or other nourishing material.[1] In its growth the mycelium helps to effect decay, and may thereby enrich soils, or, in the case of mushrooms that grow upon living trees, it may hasten their destruction. At times aggregations of the mycelium are formed; these are whitish, bud-like growths (called buttons), which are the beginnings of the

FIG. 199. The "shaggy mane" mushroom (*Coprinus comatus*)

At the left of the main group is one young mushroom just emerging from the soil. The tallest plant in the photograph was 9½ inches high. From A. H. R. Buller's "Researches on Fungi"

mushrooms. They grow and push their way to the surface. As the button elongates, its top begins to expand into the umbrella-like form, and finally opens out as the crown, or pileus, with its center attached to the upper end of the stalk (*stipe*) (figs. 199 and 200). As the pileus opens, it is joined

[1] "The Principles of Mushroom Growing and Spawn Making," *Bulletin 85*, Bureau of Plant Industry, U.S. Dept. Agr., 1905. The United States Department of Agriculture publishes several bulletins upon poisonous and edible fungi.

to the stalk beneath by means of a layer of hyphæ (the *veil*). In some species, when the veil breaks away from the pileus, it forms a ring, or *annulus*, about the stalk.

The underside of the pileus is made up of plate-like growths (*gills*) which radiate from the stalk. Some of the hyphæ which compose the gills extend from the surface of the gill,

Fig. 200. A poisonous fungus (*Amanita muscaria*)

From A. H. R. Buller's "Researches on Fungi"

and upon this extended tip (the basidium, or stalk) four (rarely two) branches are formed. Upon the tip of each branch a spore (*basidiospore*) is formed (fig. 201). When the spores fall upon moist, warm, nutrient material, they produce a new mycelium. If the pileus of a ripe mushroom is cut from the stalk and placed, with the gills downward, upon a piece of ordinary white or blank paper, after a few hours a spore print composed of thousands of spores will be made.

245. Different forms and habits of mushrooms. While the types of mushrooms already discussed and shown in the illustrations are probably most common of all, others are almost equally abundant. A common form is *Polyporus* (many pores) (fig. 182), which appears in shelf-like outgrowths from bodies of trees within which its mycelium grows. It is commonly

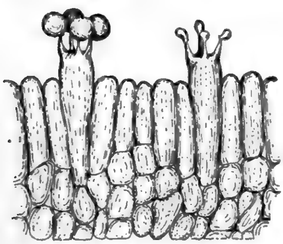

FIG. 201. Basidia and spores of a mushroom

Magnified 370 diameters. After A. H. R. Buller

spoken of as one of the tree-destroying fungi. The mycelium is able to penetrate through woody tissues and to extend for great distances within the host plant. It may infect a living tree when a broken limb or other injury offers an entrance, live within it during the life of the tree, and thereafter help to bring about the decay of the tree. The shelf-like reproductive portion, instead of bearing gills on the under surface, has many small pores within which spores are formed. The number of these spores is very great; one authority [1] estimates

FIG. 202. Puffballs

Two species of puffballs of the genus *Lycoperdon*. Those above are one half natural size; that below is two ninths natural size

[1] Buller, A. H. R., Researches on Fungi. Longmans, Green & Co., 1909.

that a single plant (*Polyporus squamosus*) may produce as many as 11,000,000 spores. The same authority states that one "shaggy mane" (*Coprinus comatus*) mushroom may produce 5,000,000,000 spores. It is obvious that only a small number of these spores succeed in producing new plants; otherwise they would very soon occupy the earth.

246. Puffballs. One of the most important differences between puffballs (fig. 202) and mushrooms is that puffballs produce their spores within an inclosed reproductive body instead of upon gills or within pores. Puffballs may become quite large, even a foot in diameter, and, when ripe, may continue to emit small clouds of spores intermittently for several years. One giant puffball (*Lycoperdon giganteum*) was estimated [1] to contain 7,000,000,000,000 spores.

247. Classification of the thallophytes. The following is the classification of the thallophytes, including the chief genera that we have considered. This classification is placed here for use as a general summary, and not primarily to be committed to memory. If studied carefully, it will give a good review of the three chapters on the groups of thallophytes.

GROUP A. THALLOPHYTES. Since the bacteria and the blue-green algæ are so much alike in structure and in methods of reproduction, they are classified together rather than with the fungi and algæ respectively.

- CLASS I. SCHIZOPHYTES (the fission plants)
  - SUB-CLASS I. SCHIZOMYCETES (bacteria, or fission fungi). Illustrated by numerous type forms and various methods of living
  - SUB-CLASS II. SCHIZOPHYCEÆ, or Cyanophyceæ (the blue-green algæ, or the fission algæ). Leading genera used as illustrations — *Nostoc, Oscillatoria*
- CLASS II. ALGÆ
  - SUB-CLASS I. CHLOROPHYCEÆ (the green algæ). Leading genera used as illustrations — *Pleurococcus, Spirogyra, Cladophora, Vaucheria, Chara*
  - SUB-CLASS II. PHÆOPHYCEÆ (the brown algæ). Leading genera used as illustrations — *Fucus, Sargassum*
  - SUB-CLASS III. RHODOPHYCEÆ (the red algæ). Leading genus used as illustration — *Dasya*

[1] Buller, A. H. R., Researches on Fungi. Longmans, Green & Co., 1909.

CLASS III. FUNGI

SUB-CLASS I. PHYCOMYCETES (the algæ-fungi). Leading genera used as illustrations — *Rhizopus* (bread mold), *Plasmopara* (grape downy mildew), *Phytophthora* (potato blight)

SUB-CLASS II. ASCOMYCETES (the sac fungi). Leading genera used as illustrations — *Sclerotinia* (brown rot), *Miscrosphaera* (lilac mildew), *Morchella* (morel), *Penicillium* (blue mold), *Saccharomyces* (yeast)

SUB-CLASS III. LICHENS. Leading genera used as illustrations — *Parmelia, Usnea* (bearded moss), *Cladonia*

SUB-CLASS IV. BASIDIOMYCETES (the basidium fungi). Leading genera used as illustrations — *Ustilago* (smut), *Puccinia* (rust), *Coprinus* and *Polyporus* (mushrooms), *Lycoperdon* (puffball)

PROBLEMS

1. Why does bread "mold"? How can it be prevented from doing so?

2. Why is it that a plant disease newly introduced into a country seems to spread more rapidly and to prove more destructive than diseases that have long been in that country?

3. Can you account for the fact that lilac bushes seem to be fairly thrifty even though they are infested with lilac mildew?

4. Why are lichens sometimes called "the advance guard of vegetation"?

5. If you can secure the data from published reports, or can perform an experiment for the purpose, determine the difference in yield that may be made by selecting or treating seed oats or corn so as to remove the smut disease. What percentage of gain on the crop may be made in this way?

6. Under what circumstances may fungi that are parasitic upon plants or animals be of service to the farmer or gardener?

7. Why are railroad ties and other timbers often treated with poisonous solutions before they are used?

8. Discover from first-hand study or from publications the life history of some of the worst fungous parasites of your locality.

CHAPTER XVII

MOSSES, LIVERWORTS, AND FERNS

248. Introductory. The mosses belong to the second great division of the plant kingdom, the *bryophytes*, which means "moss plants." All small, green plants are commonly called mosses, but when we discover what kinds of plants mosses are, we shall see how incorrect such a general use of the term is. The bryophytes also include another group, the liverworts, which are peculiar and infrequently noticed plants. The mosses, on the contrary, are extremely abundant and grow in almost all kinds of places. The ferns (*pteridophytes*, which means "feather plants," or "fern plants") constitute the third great division of the plant kingdom and will be considered after the bryophytes. It is so much easier to get clear notions of the bryophytes by a study of the mosses, that we shall give our chief consideration to them, rather than to the liverworts, which are simpler in some ways but less common and less easily studied than mosses.

249. The moss plant. Careful observation of any common moss will enable one to see that it has green, leaf-like structures arranged around a very small stem. Sometimes also there appears upon this leafy stem a slender stalk with a swollen, pod-like tip, or capsule (fig. 203, *C*). In this tip many simple asexual spores are formed, and if we follow the life round of the moss, beginning with the development of one of these spores, we shall get a good notion of the nature of the structures of the moss plant.

Upon the germination of the asexual spore there grows from it a filament, or thread, which looks so much like the algæ that it is often extremely difficult to distinguish it from them.

Its cells contain chloroplasts and can manufacture their own food. Since this filament precedes the leafy moss plant, it is called the *protonema*, which means "first thread" (fig. 203, *A*).

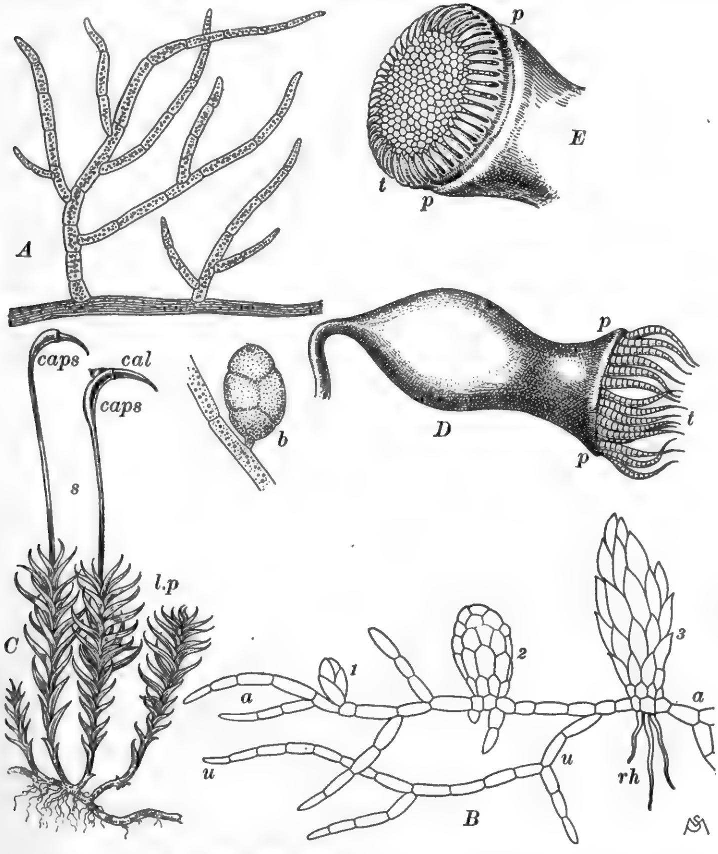

FIG. 203. The life cycle of a moss plant

A, branching protonema, magnified 50 diameters. *B* and *b*, protonema producing buds (1, 2, and 3), rhizoids (*rh*), and underground branches (*u*); magnified 40 diameters. *C*, adult leafy plants (*l.p*), upon which are the sporophytes (*s*) with their capsules (*caps*), in which spores are borne, the capsule tip being covered by the hood, or calyptra (*cal*); natural size. *D* and *E*, enlarged capsules with the mouth, or peristome (*p*), from which the teeth (*t*) extend; magnified 25 diameters. All are the moss *Atrichum undulatum* except *D*, which is *Fissidens adiantoides*. *A* and *B* from Bonnier and Sablon; *C*, *D*, and *E* from Braithwaite

In moist and shady places protonema may grow until great mats are formed upon the soil, old logs, etc., and in these places the alga-like protonema may live for several years.

At times some of the protonemal cells produce outgrowths which divide by oblique walls and form buds (fig. 203, *B* and *b*). The buds may become dormant and lie for months or even longer, and then continue to grow; or there may be no resting period. When they grow, the outermost cells produce leaves, the central ones become the stem, and from the lower ones the root-like hairs (rhizoids) grow. The rhizoids descend into the soil or other substance below the plant, and the leaves and stem rise into the air. The buds, therefore, which grow from the protonema are the beginnings of the leafy moss plant.

250. Sexual and asexual reproduction in the moss. At the tip of the stem of the leafy plant, more or less inclosed by the leaves, the sex organs of the moss develop. These are of two kinds, and with them there are usually taller sterile filaments, which bear chlorophyll and may serve to protect the sex organs. In some kinds of mosses only one kind of sex organ is borne on a single plant, while in other kinds both are produced on the same plant at the same time. Neither can be studied without magnification, although the male sex organs may sometimes be detected without a lens.

The *archegonium*, the female sex organ, is similar in function to the oögonium in *Vaucheria*. It is flask-like and has an elongated neck (fig. 204, *D*). In the swollen part of the archegonium the egg is formed. When the egg is mature, the central cells of the neck become gelatinous, and the end of the neck opens so that there is a passageway through the neck down to the egg. The male sex organ, the *antheridium*, is club-shaped (fig. 204, *A*), being attached by its smaller end to the tip of the plant stem. When the antheridium opens, its thousands of sperms are set free. The sperms swim with great activity, and some of them may come into the vicinity of the neck of the archegonium. One or more make their way down through the gelatinous neck of the archegonium to the

egg, where one of them unites with the egg, thus producing an oöspore, or sex spore.

The oöspore does not have a resting period, as in *Vaucheria*, but begins its growth almost immediately when formed. It enlarges, divides into many cells (that is, it grows), and soon elongates into a stalk one end of which is attached to the old

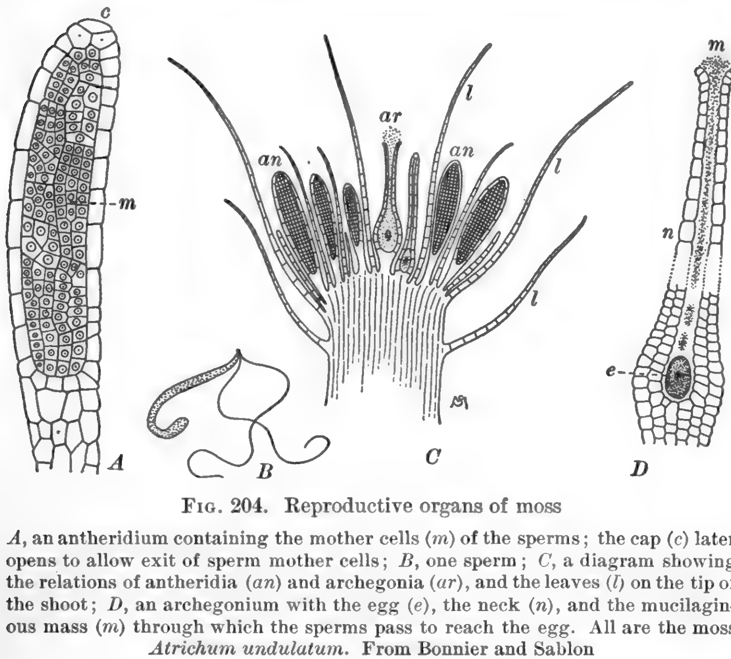

Fig. 204. Reproductive organs of moss

A, an antheridium containing the mother cells (*m*) of the sperms; the cap (*c*) later opens to allow exit of sperm mother cells; *B*, one sperm; *C*, a diagram showing the relations of antheridia (*an*) and archegonia (*ar*), and the leaves (*l*) on the tip of the shoot; *D*, an archegonium with the egg (*e*), the neck (*n*), and the mucilaginous mass (*m*) through which the sperms pass to reach the egg. All are the moss *Atrichum undulatum*. From Bonnier and Sablon

leafy stalk, and the other extends up above the leaves. The stalk which grows from the oöspore bears chlorophyll. A capsule is produced at the tip of this new stalk, and spores are formed by the division of part of the inner tissues of the capsule. Since these spores are formed by division of tissues and not by union of cells, it is obvious that they are asexual spores. When they fall to the ground, they produce protonema again, and thus begin another life round of the moss plant. The

capsule in which the asexual spores are formed is a complex structure. The stalk upon which it is borne is known as the *seta*, which means "bristle" or "hair." In the capsule itself the cap which covers the tip is known as the *calyptra*, which means "hood." The calyptra is the old archegonium wall that was carried upward by the developing stalk. Beneath the calyptra is the mouth, or *peristome*, of the capsule, and over the mouth is an easily removed lid, the *operculum*. Beneath this lid peculiar *teeth* (fig. 203, *D* and *E*) surround the mouth, and through these teeth the spores are dropped or thrown as changes in moisture cause the teeth to move in and out. This elaborate arrangement is thought to secure thorough distribution of the asexual spores of the mosses.

251. Alternate stages in the life of the mosses. It is evident that in the mosses sexual and asexual reproduction are limited to distinct parts of the plant. A moss spore, when it germinates, produces not the part of the plant from which the spore grew, but the other part. Asexual spores germinate and produce protonema, from which the leafy shoot grows by means of buds; the sex spore, or oöspore, germinates and produces the leafless stalk, upon which grows the capsule in which asexual spores are formed. It is customary to speak of that part of a plant which produces the asexual spores as the *sporophyte* (spore plant), and of the part that produces the sex spore as the *gametophyte* (gamete plant), or the part of the plant which produces the sex cells. The sporophyte is therefore the asexual generation of the moss, and the gametophyte the sexual generation, and they alternate in completing the life round of the whole plant. This relation of the two phases is spoken of as the alternation of generations. The fact that the protonema and the leafy shoot are distinct structures does not make a third phase in the alternation, for the reason that there is no spore intervening between them. Also, the term *alternation*, as used, refers only to sexual and asexual generations, and not to cases such as that of the wheat rust, where the asexual phase appears in several different forms.

252. The nutrition of mosses. The stem-and-leaf arrangement of the mosses exposes chlorophyll to the light in a different way from that which was found in the algæ. With the leaves arranged radially about the stem much more chlorophyll is exposed than could be exposed in the same space by a prostrate plant. The importance of the stem in holding these leaves up into the air, thus making the radial arrangement possible, is great. The expanded portions of the leaves are a single layer of cells in thickness, while the median portion may consist of several layers. Moss plants are often favorably placed for securing moisture when moisture is abundant. The whole dense growth made by the hundreds of plants that grow together may act as a sponge in absorbing and holding water, so that at times, when one is walking through mosses, water runs in streams from those upon which he steps. Certain mosses live part or all of the time directly in the water. On the other hand, when long exposed to drying influences, some mosses become so dry that they readily crumble; but if not disturbed, they proceed to grow whenever there is a return of adequate moisture. Mosses may also withstand great extremes of heat and cold.

Fig. 205. A peat-bog moss (*Sphagnum*)

About natural size

253. Peat-bog moss. There are many different kinds of mosses, and they are found in almost all kinds of places where any plants grow. Peat-bog moss (*Sphagnum*) (fig. 205) is a very striking form which, with other plants, often forms peat.

It may grow about the edge of the water or upon extremely wet soil that has been formed by the partial decay of plants. On account of the peculiar structure of the leaves these plants hold water in great quantities. The leafy shoot of *Sphagnum* continues its growth at the tip from year to year, while the older submerged portions gradually become partially decayed and intermingled with other plant material. A semi-solid surface of soil is gradually formed, and this often supports many kinds of plants beside *Sphagnum*. After long periods of accumulation the partially decayed material becomes compressed by the increasing weight above it and is known as peat. When removed and dried (sometimes compressed into bricks), it is used as fuel and finds a market in many parts of the world. *Sphagnum* is quite commonly used as a packing material and also for holding moisture about potted plants.

254. General characteristics of the liverworts. These peculiar plants (fig. 206) take their name from their supposed resemblance to the human liver. Most of them grow in moist, well-shaded regions, though sometimes they are quite exposed and in a few cases they may even grow in intense light and heat. Few of them look much like mosses, but some have leaf-like structures which quite closely resemble them.

The most commonly found liverworts lie flat upon the ground or upon whatever supports them. From the under-surface many rhizoids grow. The plants are usually dark green, being abundantly supplied with chlorophyll. They grow forward, the lobes continuing to branch until solid mats are formed. Older portions of the plant die, leaving the younger branches as new and independent plants.

In some liverworts, cups form on the upper surface, and in these cups small, flattish, green buds are developed. These buds, when they fall from the cups or are removed in some other way, may grow into new liverwort plants. Also, in such liverworts as those shown on page 269, upright stalks grow from the prostrate parts of the plants, and in the heads that are produced on the ends of these stalks the sex organs are

formed. Special antheridial heads produce antheridia and sperms, and special archegonial heads produce archegonia and eggs. The sperm unites with the egg within the archegonium on the underside of the archegonial head, thus forming the oöspore. The oöspore grows and produces an inconspicuous sporophyte, which in turn produces asexual spores.[1]

255. General facts about ferns. The third great division of the plant kingdom is usually spoken of as the ferns (*pteridophytes*). The group includes other classes, two of which are

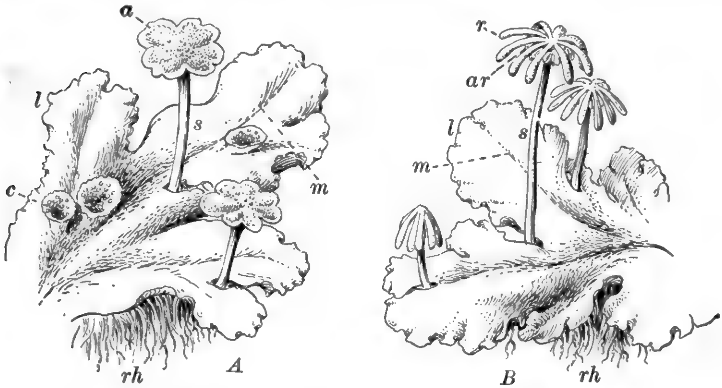

FIG. 206. A common liverwort (*Marchantia*)

A, an antheridial plant; *B*, an archegonial plant; rhizoids (*rh*) and midrib (*m*) of the leaf-like flattened body (*l*); capsules (*c*), in which vegetative reproductive buds are formed; the upright stalks (*s*) are antheridial (*a*) and archegonial (*ar*), the latter being distinguished by peculiar rays (*r*). Slightly more than natural size

the scouring rushes, or horsetails, and the club mosses. There is good evidence that ferns were formerly more numerous upon the earth than they now are, and some of the early ferns were of much larger size than those that now exist. During the times when coal was being formed most abundantly, ferns and their near relatives composed a conspicuous part of the flora. Some

[1] Discussion of the different kinds of liverworts and the details of liverwort reproduction are not important for most elementary classes. In special cases where it is deemed best to make further study, see Bergen and Davis, Principles of Botany.

of these ancient plants doubtless represented classes that are extinct, and others were the older members or the ancestors of the classes which we now have, which in some cases are represented by only a few kinds of living plants.

Most ferns grow in moist regions, but some species are found in peculiarly dry situations, even growing like lichens on nearly

Fig. 207. A group of maidenhair ferns

Photograph by W. H. P. Huber

bare rocks. Although they show considerable variation in form, they can in nearly all cases be distinguished from other plants by their greatly divided, feather-like leaves (fig. 207). Ferns have great range in size, from very small, lowly plants to those as high as a man's head, and to the tropical tree ferns that may be forty feet or more in height. They may occur singly or in thickets so dense as to make it difficult to penetrate them. In all except the tree ferns the parts of the plant that we see are the leaves; the stems and the roots are underground.

256. The rootstock of a fern. If the soil is carefully removed from the underground part of one of the common ferns, the horizontal rootstock (*rhizome*) appears (fig. 208). The lower side of the rhizome gives rise to the roots, and the upper side bears the leaves. At the tip of the rootstock is the bud, by means of which growth is continued from year to year. The leaf scars, or the bases of old leaves, may usually be seen upon the rootstock. The terminal bud grows forward each year from a fraction of an inch in some ferns to several inches in others, and at the beginning of each season it sends up one or more new leaves.

FIG. 208. The bracken fern (*Pteris aquilina*)

The rootstock (*rh*) is horizontal and grows underground; upon it are the buds (*b*) and the upright leafstalk (*st*)

The rhizome of the fern (fig. 209) presents the first really complex stem structure that we find as we study the groups of plants in the order of their increasing complexity. This is a woody stem composed of several kinds of stem tissues. Some of these tissues are heavy-walled and give rigidity to the stem. The rhizome is sometimes stored full of food in the form of starch. Some of the tissues consist chiefly of rounded, fiber-like bundles which extend lengthwise throughout the stem. These are the *fibrovascular bundles*, which term simply means "fibrous bundles of vessels."

257. The leaf of a fern. As a fern leaf develops from the bud, it unfolds in a very peculiar fashion (fig. 211) known as *circinate vernation*. The coiled or rolled (circinate) tip of the leaf is easily seen even in most old fern leaves. Mature fern leaves assume so great a variety of forms that it is impossible to give any description that holds good for many kinds,

and no such description is here attempted. In all leaves the fibrovascular bundles extend throughout the leafstalk into the leaves, where they are known as the veins of the leaf.

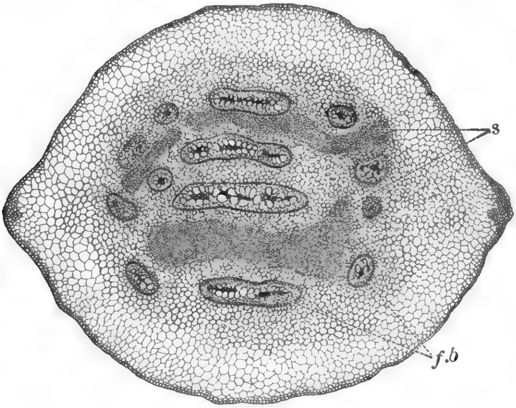

FIG. 209. The rootstock of a fern

The outer part of the stem is made up of hard tissue, and in the interior are also bundles of hard tissue (*s*) known as sclerenchyma; numerous woody bundles (*f.b*) are also surrounded by the large amount of pith

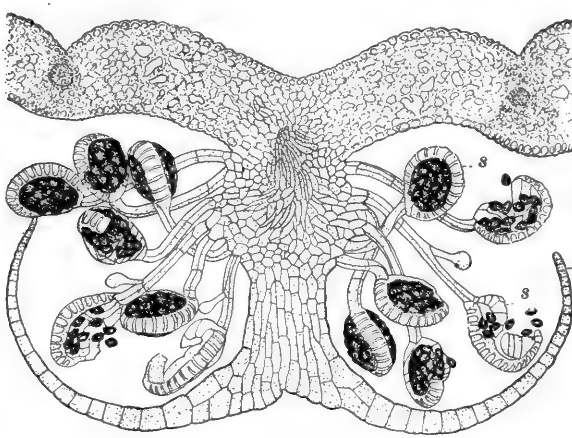

FIG. 210. Diagram of cross section of a fern leaf

On the underside of the leaf are the indusium (*i*) and the sporangia (*s*); within the sporangia are the spores. After Engler and Prantl

The epidermis of the leaf is quite different from anything seen in the liverworts or mosses. When examined with the microscope, it is seen to consist of a single layer of cells, whose irregular walls fit into one another quite closely. In the lower epidermis, rarely in the upper, are the stomata (sect. 33). In a transverse section of the leaf (fig. 210) the other leaf tissues are seen. They are the veins (which appear

FIG. 211. Opening (vernation) of the leaves of Clayton's fern

A skunk-cabbage plant stands in front of the ferns

in cross section as bundles of very small, heavy-walled cells), the chlorophyll-bearing cells, and the sporangia. Between the chlorophyll-bearing cells there are many air spaces.

258. Fern sporangia. On the undersides of most fern leaves the sporangia appear from time to time (fig. 210). An entire group of sporangia is called a *sorus*. The sorus is usually partially or entirely covered by an outgrowth of the leaf known as the *indusium*. The position of the sori (plural of *sorus*) and the nature of the indusium vary widely in different ferns

(fig. 215). Within the sporangium (fig. 210) many heavy-walled asexual spores are produced. In most of the common ferns the sporangia are of the form shown in figure 210. There is a heavy ring of cells which extends over the wall of the sporangium. When ripe these cells become dry, straighten out, and tear the sporangium open; the ring of cells then springs forcibly back to its former position, and in doing so scatters the spores.

259. Sexual reproduction of a fern. The asexual fern spore germinates upon moist earth, pots in greenhouses, etc. It soon grows into a broad, flat, heart-shaped plant (fig. 212) not at all like the fern plant that we ordinarily see. This plant is one layer of cells in thickness at the margin, but along the midrib a cushion of several layers of cells is formed. From the underside and near the base many rhizoids grow. The presence of chlorophyll and contact with moist surfaces aid it in manufacturing its own food.

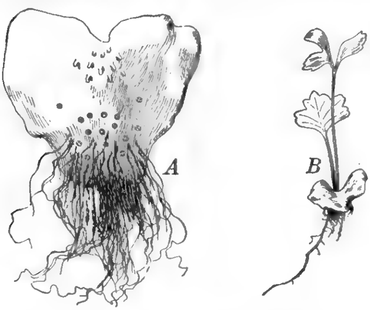

FIG. 212. Gametophyte of a fern

A, the gametophyte (magnified about ten times); *B*, young sporophyte growing from the gametophyte (magnified about three times)

Antheridia may be developed almost anywhere upon the plant before it has become fully heart-shaped, and thereafter they usually develop on the underside, toward the basal region (fig. 212). The antheridium is a globular structure with a single layer of wall cells (fig. 213) and a central region in which usually thirty-two or sixty-four sperms are formed. In size and number of cells this antheridium is much simpler than that seen in the bryophytes. The sperm is, however, quite complex and seems well constructed for swimming.

On the underside of the plant and nearer the tip region are the archegonia (figs. 212 and 214). Only the necks extend outward from the surface, and these usually turn backward,

toward the antheridia. The enlarged part of an archegonium, where the egg is formed, is imbedded. The neck opens, sperms enter, and one of the sperms unites with the egg. The result is the formation of an oöspore, which is inclosed in the tissue. Since this heart-shaped plant produced the sex cells, it is the gamete plant, or gametophyte, and since the asexual spores are formed upon the leafy fern plant, that is the sporophyte. The asexual spore germinates and produces the gametophyte, and the oöspore germinates and produces the leafy

FIG. 213. Fern antheridium, with sperms

Greatly magnified

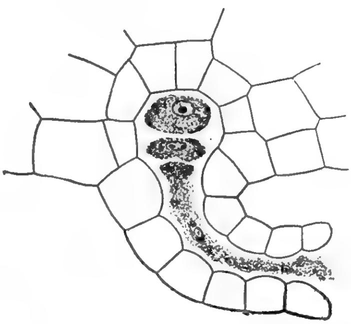

FIG. 214. Archegonium of a fern

Greatly magnified

sporophyte. The young leafy plant at first appears as if it grew directly from the heart-shaped gametophyte (fig. 212). It soon develops leaves and roots and an underground stem — in short, is a new leafy fern plant.

It must be clear that in ferns there is the same kind of alternation between the sexual and asexual generations of the plant as that seen in the mosses, except that in the ferns each stage of the plant lives for a time quite independent of the other stage.

260. Significance of fibrovascular tissue. It is evident that a fern leaf exposes much chlorophyll to the light — much more than does any plant among the bryophytes. The strong supporting and conducting tissues of the leaf uphold the

chlorophyll-containing tissues in such a position that they may receive light; at the same time, through the fibrovascular bundles of the leafstock and the rhizome, soil water and substances in solution may be transported to the chlorophyll tissue. The root system anchors the plant in the earth and absorbs the water needed in food manufacture.

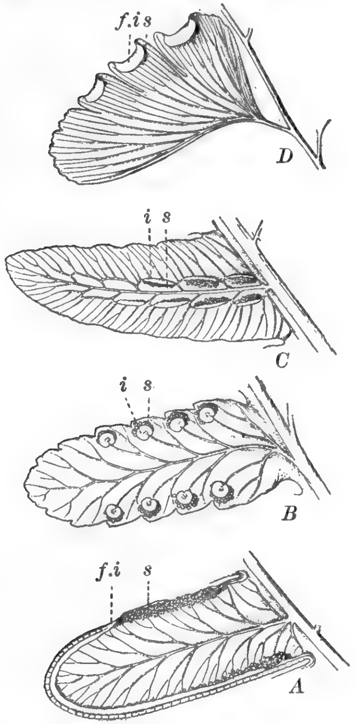

FIG. 215. Types of fern leaflets

A, bracken fern; *B*, shield fern; *C*, spleenwort; *D*, the maidenhair fern. In the different specimens the sporangia are at *s*, the indusium at *i*, and the false indusium at *f.i*

In general, plants that rise above the soil and into the air must be supported and must secure water from some source. The climbing vines which are dependent upon other plants are supported chiefly by these other plants. Most vines procure their supply of water from the soil and transport it by means of their own vascular tissue. Fibrovascular tissue, by reason of its strength, makes possible the upright position and is essential (as is also the absorbing and anchoring root system) alike to the fields of upright grain and to the forests. The importance of vascular tissue in ferns and higher plants can hardly be over-estimated.

261. Types of ferns. Ferns are usually distinguished from one another by the leaves, the sori, and the sporangia. There is much variation in position and arrangement of sori in different ferns (fig. 215). In some the sori are dots placed regularly upon the leaf. In others they are like slits or blistery

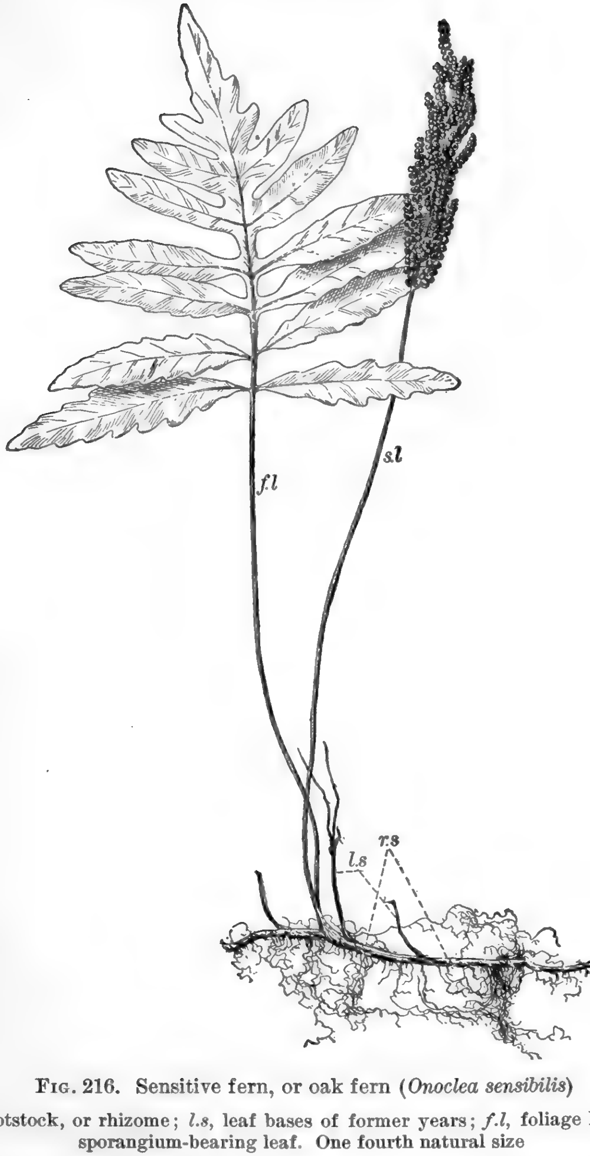

FIG. 216. Sensitive fern, or oak fern (*Onoclea sensibilis*)

r.s, rootstock, or rhizome; *l.s*, leaf bases of former years; *f.l*, foliage leaf; *s.l*, sporangium-bearing leaf. One fourth natural size

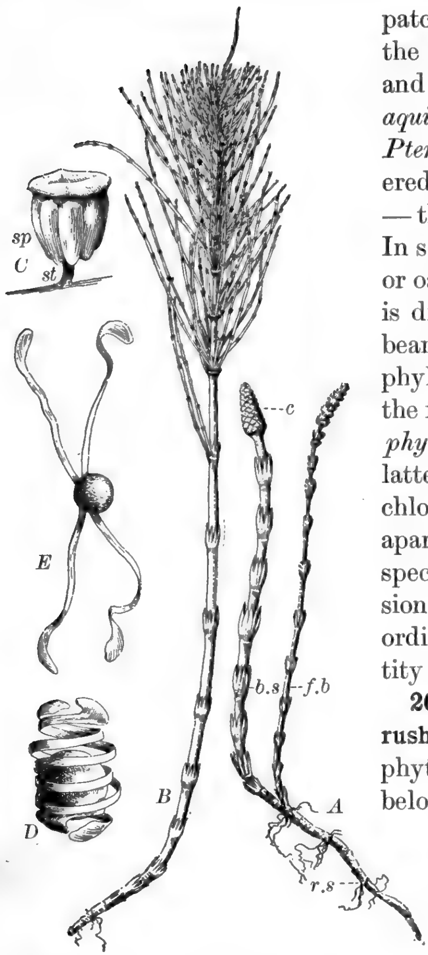

FIG. 217. The common scouring rush, or horsetail (*Equisetum arvense*)

A, a plant in early spring condition; *r.s*, rhizome; *b.s*, spore-bearing branch; *c*, collection of sporophylls (strobilus, or cone); *f.b*, foliage branch, which later expands as in *B*; *C*, one sporophyll from the cone, showing the stalk (*st*) and several sporangia (*sp*). *D* and *E*, spore with elaters. *A* and *B*, one half natural size; *C*, magnified about 20 times; *D* and *E*, greatly enlarged

patches. In still others, as the maidenhair (*Adiantum*) and the bracken fern (*Pteris aquilina*) and other species of *Pteris*, the sporangia are covered by the folded leaf margins — the so-called false indusium. In some, as the sensitive fern, or oak fern (fig. 216), the leaf is differentiated into a spore-bearing branch and a chlorophyll branch. In such cases the former is called the *sporophyll* (spore leaf), and the latter the *foliage* leaf, the chlorophyll bearer. Setting apart special structures for special pieces of work (division of labor), as here shown, ordinarily increases the quantity and quality of work done.

262. Horsetails, or scouring rushes. The class of pteridophytes to which these plants belong once constituted a prominent part of the earth's flora as tree-like plants. They are now represented by the single genus *Equisetum*. Fossil remains tell interesting stories of the ancestors of these plants which lived ages ago when coal was being formed in abundance.

Modern equisetums live about open marshes, in sandy wastes, and along railroad embankments. They have hard, rough, siliceous stems, with small leaves that form sheaths about the joints of the stem (fig. 217). In the most common species of *Equisetum* the sporophyll branch appears very early in the spring and produces at its tip the strobilus, or cone, which bears the sporangia upon greatly reduced and transformed leaves (sporophylls). The bushy chlorophyll branch appears later and is the one which grows throughout the season, the sporophyll branch disappearing as soon as the spores have been shed. The spores are attached to peculiar strap-like outgrowths known as elaters (drivers). The elaters are supposed to assist in distributing the spores.

The bushy foliage, or chlorophyll part of the plant, grows and deposits its food material which may be used the next season for the growth of the sporophyll branch.

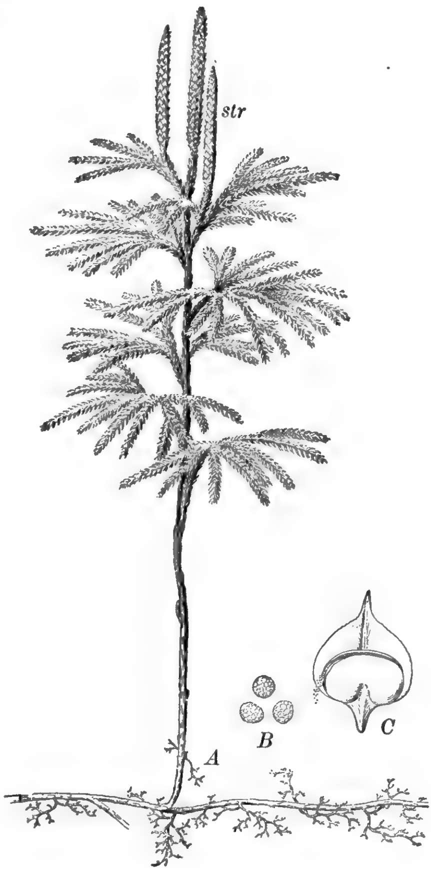

FIG. 218. A club moss (*Lycopodium*)

The horizontal rootstock, with its roots, grows within or upon the humus. The upright branches (*A*) bear green leaves and strobili (*str*) (also called spikes or cones) in which spores are formed. At *C* is shown one leaf from the strobilus, and upon this leaf is a sporangium. From the partially opened sporangium, spores escape. *B* shows enlarged spores

263. Club-mosses, or ground pines. These plants constitute another class of the pteridophytes. The most common ones belong to the genus *Lycopodium* (fig. 218). *Lycopodium* plants are found mostly in the cooler temperate regions. At Christmas time they are shipped and used extensively in decoration throughout the United States. Their stems, which are underground or under leaves, etc., their upright branches and symmetrically arranged leaves, and their prominent spore-bearing cones are striking features of these plants. The collections of sporophylls in these plants and in *Equisetum* are sometimes spoken of as flowers but are more properly called strobili, or cones.

264. Pteridophytes of past ages. The surface of the earth has undergone many sweeping changes since plants first began to live upon it. In some periods of the earth's history conditions favored certain kinds of plants, and these flourished. When less favorable periods came, these once-successful plants were greatly reduced in number, or possibly were eliminated. We have records of what some of these former plants were. These records were made by the plants themselves, for when they died they sometimes became fossilized, or made prints in soft mud or other substances which afterwards hardened. By means of fossils much is being learned about the kinds of plants that used to exist. The ancient fern-like plants were widely distributed over the earth. Certain periods (as the so-called carboniferous period) were peculiarly favorable in temperature and moisture to the growth of pteridophyte types of plants, and they grew to much greater size and in much greater profusion than even our present tree-ferns of the moist tropics. After a long period of growth, when multitudes of the plants had died and fallen, conditions changed and these masses of plant material became submerged and then buried beneath layers of rock and earth, and at length coal was formed from them.

265. Classification. The following classification may assist in keeping leading facts in mind, but it is presented as a means of review rather than as an outline to be committed to memory.

GROUP B. BRYOPHYTES

CLASS I. HEPATICÆ (liverworts). Genus used as illustration — *Marchantia*

CLASS II. MUSCI (mosses). Leading genera used as illustrations — *Atrichum* and *Sphagnum*

GROUP C. PTERIDOPHYTES

CLASS I. FILICINÆ (the true ferns). Leading genera used as illustrations — *Pteris* (the bracken fern), *Adiantum* (the maidenhair fern), *Onoclea* (the sensitive fern, or oak fern)

CLASS II. EQUISETINÆ (horsetails, or scouring rushes). Genus used as illustration — *Equisetum* (the only living genus of the class)

CLASS III. LYCOPODINÆ (club mosses or ground pines). Genus used as illustration — *Lycopodium* (one of the three living genera of the class)

PROBLEMS

1. Of what importance are mosses as soil formers?

2. What is the significance of the radial arrangement of the leaves of the moss plants?

3. Why is it important to the plants that the asexual spores of mosses, liverworts, and ferns should have wide distribution?

4. In what sense is it true that the vascular tissue exemplified in ferns means about the same to the plant kingdom as the vertebral column (backbone) means to the animal kingdom?

5. Why is it that peat-bog moss is good material for covering the soil of potted plants and for packing fragile articles for shipping?

6. In what ways may ferns be propagated vegetatively? How do florists propagate their ferns?

7. What structures of ferns help to explain the fact that most ferns thrive best in damp and shaded regions?

8. In museums that you have visited what fossil evidences are there that ferns lived during former ages?

CHAPTER XVIII

THE SEED PLANTS[1]

266. Introductory. In the earlier chapters of this book we dealt only with flowering or seed plants, which belong to the fourth great division of the plant kingdom. This division is known as the spermatophytes, which means "seed plants." In fact, our earlier discussions considered practically no plants except members of the second of the two groups of seed plants — the angiosperms, or plants with inclosed seeds. The other group of seed plants is the gymnosperms, or plants with exposed seeds. Seed plants are the most conspicuous plants of the earth, and are the ones which people ordinarily regard as composing the plant kingdom. They are most important in agriculture, horticulture, landscape and vegetable gardening, forestry, and the industries. We shall first consider the gymnosperms, of which there are over four hundred species, some widely distributed and some limited to small areas.

267. Gymnosperms — the pine as a type. The pine is the best general illustration of the gymnosperms and is by far the most widely distributed member of the group. Sometimes pines form dense forests of tall, straight trees standing close together. It is only when thus crowded that they grow tall, since, when growing alone in open territory, they secure ample light without attaining such a height.

With a deep-growing central taproot and extensively branched lateral roots the pine plant holds its place in the

[1] This chapter summarizes some of the things said about seed plants in the first chapters of this book, and adds discussions which will enable the student to see in an elementary way the relation of the seed plants to the groups of lower plants discussed in the immediately preceding chapters.

soil and supports the heavy stem and branches. The stem is generally straight, and the branches usually rise in whorls. The lower branches are longest, so that the whole tree presents a cone-like outline (fig. 219). A heavy bark of a kind not seen in any of the lower plants covers the roots, stem, and branches. Leaves are borne only on the younger branches. The small scale leaves are inconspicuous, while the needle leaves are the ones usually observed.

Fig. 219. A white pine (*Pinus Strobus*)

The stem is almost straight, the branches stand approximately at right angles to the stem, and the top is irregularly conical

268. Needle leaves. The needle leaves are borne in pairs (fig. 220), in threes, fives, etc., the number varying with the different species. The number of leaves in a cluster is one of the distinguishing characteristics of the species of pines; for example, the white pine (*Pinus Strobus*) has five leaves in a cluster, the scrub pine (*Pinus divaricata*) and others have two leaves in a cluster, the Georgia long-leaf pine (*Pinus palustris*) has three, and others have a variable number (from two to five) in each cluster.

If one of the clusters of needle leaves is pulled away from the branch that bears it, and its basal scale leaves are removed, there will be seen a very small white branch upon which the

needle leaves grow. The needle leaves are really continuations of these small branches. The inward faces of the leaves are so arranged that all of one cluster, when put together, compose a cylindrical leaf mass. That is, when two leaves compose the cluster, the leaf branch is divided into halves; when three or five are in one cluster, the branch is divided into three or five parts.

FIG. 220. A branch of a pine

At the left is a one-year-old cone (*c*), and at the tip of the shoot (*s*) a very young cone (*yc*) just open and ready to receive pollen. On the young shoot are the young needle leaves, and at the tip is the bud (*b*), which continues the growth of the stem

Gymnosperms are chiefly evergreen (that is, keep their old leaves until after new ones have come), but some of them, as the larch, or tamarack, and the bald cypress, are deciduous (that is, shed their old leaves before the appearance of the new ones). The periods during which the leaves endure, range in different species from two to four years. By determining the age of the branches through a study of the yearly bud scars one may readily ascertain how long the leaves last on any pine tree.

The clusters of pine leaves are arranged spirally around the stem, as may be learned, when they have fallen, by an examination of the leaf scars.

269. Internal structure of needle leaves. The stiffness of pine leaves is one of their most noticeable features, and when we examine a cross section, we are able to locate the tissues that give the leaves their rigidity. The outer layer of cells, the *epidermis* (fig. 221), has an extremely heavy covering, the *cuticle;* beneath the epidermis there are other heavy-walled

cells (the *strengthening cells*). Other parts of the leaf are the *stomata,* which are deeply placed in the epidermis and are often so clogged with dust that they are quite dark in appearance;

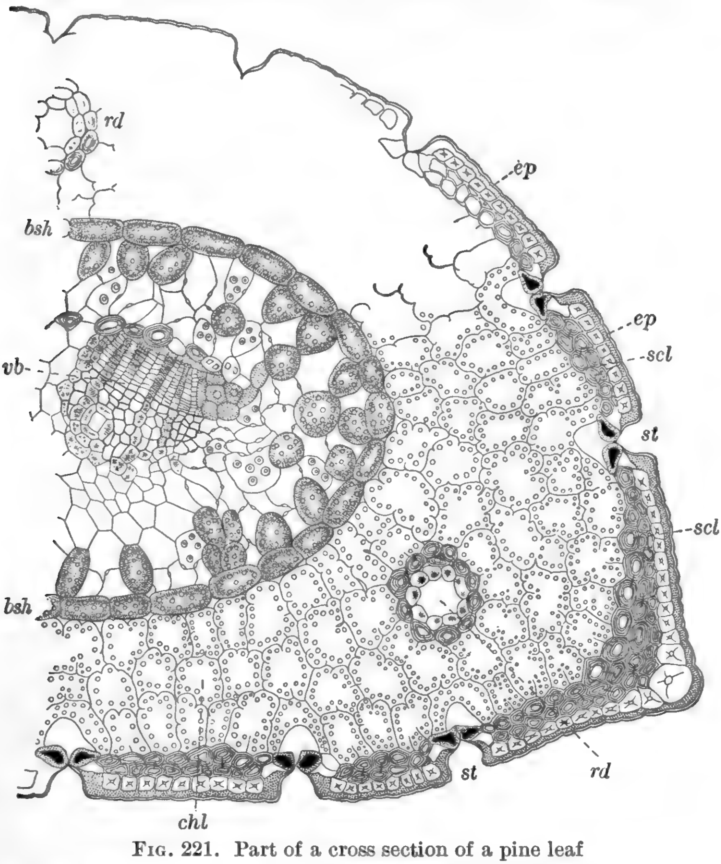

FIG. 221. Part of a cross section of a pine leaf

The epidermis (*ep*), upon which is a layer of cuticle; a layer of heavy-walled cells, or sclerenchyma (*scl*); stomata with deeply placed guard cells (*st*); chlorophyll-bearing tissue (*chl*); resin ducts, or channels (*rd*); bundle sheath (*bsh*), which incloses two vascular bundles (*vb*). Greatly magnified

the *chlorophyll tissue,* through which run the *resin ducts;* the *pith region,* through which run two groups of *fibrovascular bundles,* but one of which is shown in the figure.

The well-protected chlorophyll tissue is able to withstand severe cold and drought, and lives through periods that would kill deciduous leaves. The amount of leaf surface is comparatively small, but pine leaves probably begin their work earlier in the season than deciduous leaves do, and continue their work later.

270. New leaves and branches. When the growth buds open in the spring, the branch extends, the new needle leaves begin to elongate (fig. 220), and within a few weeks the leaves reach their full size. This new growth was started in the preceding summer and autumn, so that within the bud during the winter there were the very small stem and leaves of the next spring's growth. The scales from the growth buds fall away and leave scars, by means of which the former position of the end of the stem may be located. Also, by observing these bud scars from the tip to older portions of the branch, the age of the branch and the rate of elongation may be determined.

271. The branch and stem. From transverse sections of branches and stems of different ages their general structure may be observed.[1] Innermost is a small pith region, which in older stems is compressed until it is not usually noticeable. Around this is the woody tissue (*xylem*) of the fibrovascular bundles. The woody tissues are joined together in such a way as to form a solid woody cylinder. It is possible to determine the age of the twig approximately by counting the layers or rings of wood, except when two or more distinct growth periods occur in the same season. In such cases more than one ring would be formed in the same year. At the outer edge of the woody tissue is a thin layer of cells (*cambium*) which separates the woody tissue (*xylem*) from the outer tissue (*phloëm*). The cambium is actively growing tissue which produces new wood within and new phloëm without. The tissues outside the phloëm which we need to notice are the green bark and the dead bark. Dead bark is constantly being formed from the green bark within. This results in making the dead bark

[1] A hand lens will enable students to observe these regions of the stem.

FIG. 222. A group of "big trees" (*Sequoia gigantea*) in California

These trees grow to great size and height, one famous tree being 268 feet high. Photograph by King

constantly thicker, until finally, in older branches and stems, the light penetrates through it poorly, if at all, and chlorophyll ceases to be developed. The ridging of bark is due to the fact that bark on young branches and stems is so spread by growth within that longitudinal cracks are formed. As more wood is developed within, the spreading and thickening are increased, and ridges and crevices become more pronounced (fig. 222), as is true in most perennial stems.

272. Rate of thickening of the stem. Two of the most important of our gymnosperm trees are the white pine and the long-leaf pine. A white-pine tree overtopping most of its fellows in the forest is, on the average, at ten years 0.9 inch in diameter, at one hundred years 17.2 inches, and at two hundred years 31 inches. The average thickness of the annual rings during the life of the tree throughout its second century is therefore about $\frac{1}{14}$ inch. In the Southern pine the growth is slower. The increase in thickness of a tree two hundred twenty years old and $17\frac{3}{4}$ inches in diameter was only 1 inch during the last forty years, or $\frac{1}{40}$ inch per year.

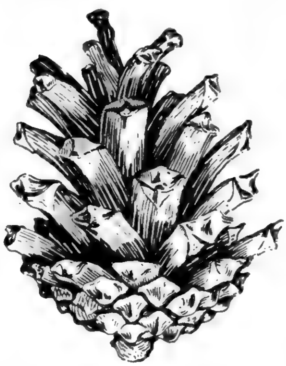

FIG. 223. Seed cone of Scotch pine (*Pinus sylvestris*) which has opened and dropped its seeds

The tallest and least shaded white-pine trees at fifty years develop new wood at the rate of about $\frac{1}{4}$ cubic foot per year; at seventy-five years at the rate of about 1 cubic foot per year, and at one hundred years at the rate of about $1\frac{1}{2}$ cubic feet per year.[1]

273. Significance of the stem. The gymnosperm stem is more complex than that of any other plant in the series of groups that we have been studying. There was vascular

[1] For further discussion of the rate of growth of pine trees see "The White Pine," *Bulletin 22*, U.S. Dept. Agr., Division of Forestry.

tissue in the ferns, but in the pines and their relatives the vascular tissue is organized into a stem that may attain great height and thickness (fig. 222). These plants have been highly successful in the struggle for light. Such plants also have quite extensive woody root systems, which serve to anchor these great trees and to gather the water and substances in solution that are conducted through the whole length of the stem to the leaves.

The significance of the stems of gymnosperms and some angiosperms to those industries that use timber is difficult to estimate. Timber is used for all sorts of useful and ornamental products, and many kinds of industry are dependent upon timber; but it must be remembered that woody stems are developed as structures which support leaves and conduct food materials to and from them, in connection with the plants' struggle to live, and that man's use of this timber is, botanically, merely incidental.

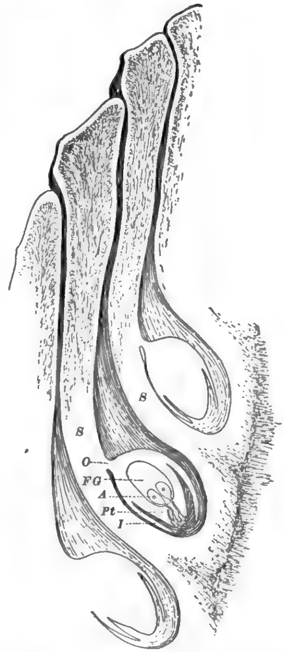

FIG. 224. Diagram of part of a seed cone of a pine, with ovules in normal position

S, sporophylls, or leaf-like parts of the cone; *O*, ovule; *I*, the covering of the ovule, called the integument; *FG*, the female gametophyte, which bears the archegonium *A*, in which the egg is formed; *Pt*, pollen tubes from pollen grains which lie upon the tip of the ovule

274. Pine cones. Two kinds of cones are borne upon pines: one is the seed-forming cone (fig. 223); the other is the staminate cone. The seed cone is composed of heavy, leaf-like parts, on the upper sides of which the developing seeds or ovules are formed. Within the ovule the egg is produced (fig. 224). The staminate cones appear early in the spring, shed their pollen, and soon wither and fall to the ground. These cones

are made up chiefly of stamens, which bear large pollen sacs (fig. 225) from which pollen is shed in great quantities. It may be carried long distances, and its transportation may be facilitated by peculiar wings, or outgrowths, upon the walls of the pollen grains. Sometimes the pollen is shed in such great abundance that some people have thought it was a shower of sulphur from some distant volcano.[1]

275. Pollination. As was learned in the chapter on pollination and fertilization, the pollen (or microspores) must be placed on the part of the flower which bears the ovules before the pollen grows. It was also learned that the proper placing of the pollen is known as pollination, and considerable study was made of the different ways in which pollination occurs. In the pines the young seed cones stand upright and open (fig. 220) at the time the pollen is being shed. If pollen grains chance to come into the seed cones, they slide down upon the leaf-like parts to the base, where the sporangia are borne. By means of a sticky secretion they are then caused to adhere to the tip of the ovule, and pollination is completed. In order that pollination in pines may be complete, it is evident that the air must be full of pollen when the ovules are ready to receive it; and this is the case. The pollen is not only very abundant but, because of its lightness, is easily transported.

276. Fertilization. In the ferns the egg is borne in the archegonium, the neck of which opens to the exterior, so that the sperm may swim directly into the passageway leading to the egg. In the gymnosperms, on the contrary, the egg is imbedded within the tissue of the ovule. After the pollen grain falls upon the ovule, there grows from its wall a tube

[1] Unfortunately for the learner, each of the structures that compose the staminate cone has had two or more names applied to it, all of which are in use in botanical writings. The pollen grains are also known as *microspores* (small spores); the pollen sacs are called *microsporangia* (small spore sacs); the stamens are called *microsporophylls* (small spore leaves); the whole staminate flower is called the *strobilus*, a name which was used for the cone of the club moss and in a way distinguishes it from the type of flower that is found in the angiosperms.

known as the pollen tube. While the tube is developing, its contents divide and produce several cells, two of which are male cells (fig. 225). The tube makes its way to the egg, and when it arrives, its tip opens and the two male cells pass out.

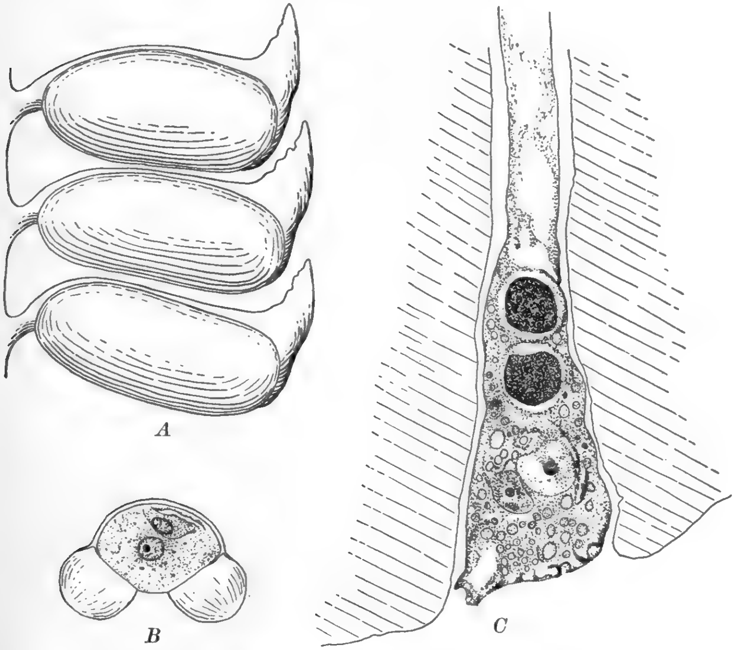

FIG. 225. Stamens, pollen, and pollen tube of the pine

A, a few of the stamens and pollen sacs from a staminate cone; somewhat magnified. *B*, an enlarged pollen grain; much magnified. *C*, the tip of a pollen tube at the time when it has almost reached the egg; just back of the two nourishing cells are the two darkly colored male cells, either of which may fertilize an egg; much magnified

Either of the male cells may unite with the egg to produce an oöspore; the other disappears. These male cells would be called sperms if they had cilia, but they have not. There are a few gymnosperms (the older ones most resembling the ferns) in which the male cells have cilia, can swim actively, and are true sperms, but even these are carried by the pollen tube.

277. Seed formation. The oöspore that is formed by the union of the sperm and the egg grows and becomes the embryo of a new pine plant. The tissues that surround this developing embryo are partly absorbed by it and used in nourishing it. By the time the embryo has developed root tip, stem tip, and young leaves, the walls of the ovule have begun to harden, and the whole structure is recognized as the seed (fig. 226). When the pine cone opens, usually two years or more from the time when pollination occurred, the seeds fall to the ground and, if conditions are favorable, begin to germinate. In germination the embryo swells and bursts the seed coat, the root grows downward into the soil, and the leaves rise into the air; in time the embryo becomes a new tree, which may bear cones and repeat the process of reproduction.

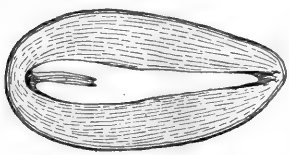

FIG. 226. Diagram of the seed of a pine, showing the embryo (new pine plant) inclosed within the food material

At the right tip of this embryo is the root, and at the left are the seed leaves which inclose the small stem tip

The cones may not shed their seeds for several years (as in the case of the lodgepole pine of the Rocky Mountains), or not even until the death of the tree, and the young plants within the seeds may still remain alive and ready to grow when properly placed for germination. It is becoming a common practice of forestry to collect pine seeds in great quantities and sow them over thousands of acres, thus resetting or extending the areas in which pine seedlings grow.

278. Other gymnosperms. There are several groups of gymnosperms, but the one to which the pines belong (the conifers) is the only one that need be mentioned here. The conifers take their name from the cone-bearing habit which is characteristic of all members of the group. In addition to the widely distributed genus (*Pinus*) already discussed, other important representatives of the conifers are the spruces (*Picea*), which have stubby needle leaves (fig. 227, *A* and *B*), close-set branches, and pendent cones; the Western hemlock, the Douglas fir

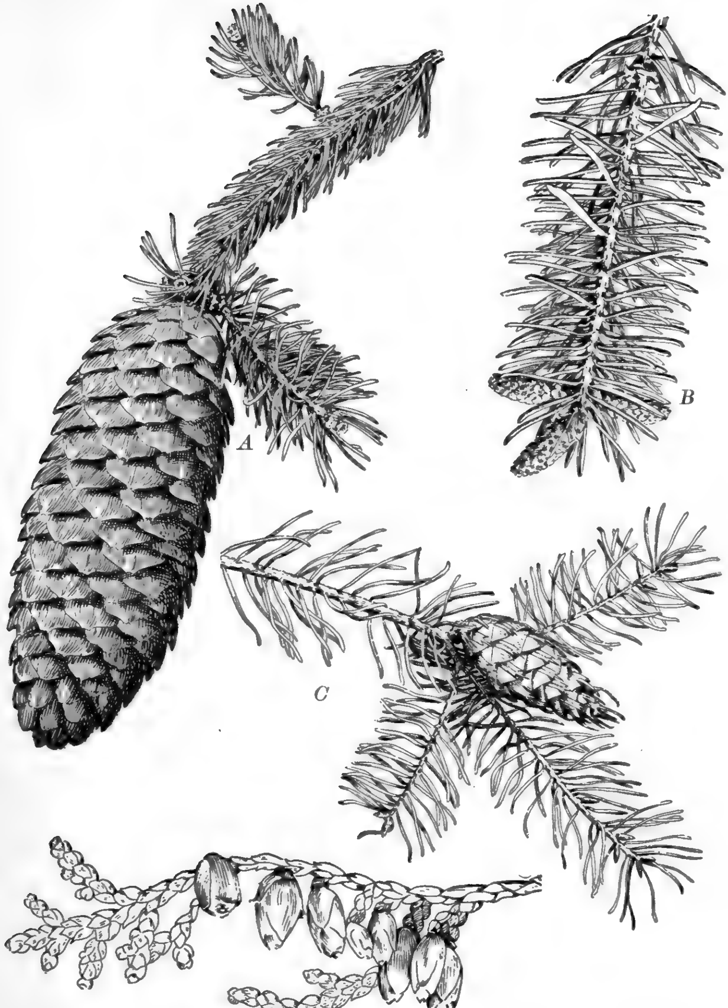

FIG. 227. A group of gymnosperm cones, of which all except *B* are seed cones

A, spruce (*Picea excelsa*), one half natural size; *B*, spruce, branch and staminate cones almost natural size; *C*, Douglas fir, or Douglas spruce (*Pseudotsuga taxifolia*), one fourth natural size; *D*, arbor vitæ (*Thuja occidentalis*), almost natural size

(fig. 227, *C*), and the fir trees (*Abies*); the Southern bald cypress (*Taxodium*), which, with the tamarack (*Larix*) of the Northern bogs, are deciduous conifers; the Northern white cedar, or arbor vitæ (*Thuja*) (fig. 227, *D*), and the Southern white cedar (*Chamaecyparis*); the red cedar, juniper, and low juniper (*Juniperus*); and the redwoods and "big trees" (*Sequoia*) of the western part of North America (fig. 222).

279. Products of gymnosperms. We naturally think of timber as the chief product of gymnosperms. By far the largest part of our primeval forests were of coniferous trees, and these are still much more abundant than all other kinds of trees. The pines and other conifers produce over three fourths of the timber of the United States. The white pine (*Pinus strobus*), the long-leaf pine (*Pinus palustris*) (fig. 229), and the loblolly pine (*Pinus taeda*) of the Southern states, the bull pine (*Pinus ponderosa*) and the sugar pine (fig. 228) of the Pacific coast and the Rocky Mountain region, and the very widely distributed spruce (*Picea*) are used in large quantities.

The western Douglas fir is a timber tree of great size and importance; the bald cypress of the South has produced immense quantities of lumber, though the available supply is becoming limited; the redwoods of the Western coast are important; but the preservation of the redwood forests is limiting their output, since natural-history interests of forests sometimes outweigh their importance as sources of lumber.

In addition to ordinary uses for construction work, railroad ties, and fuel, coniferous woods have many special uses, as the use of red cedar in making lead pencils and moth-proof chests. Several species of nut-bearing pines in western North America and one in southern Europe bear edible seeds which are used as food; valuable extracts, as pine tar, rosin, and oil of turpentine, are obtained in this country and are derived chiefly from the long-leaf pine (fig. 229).

280. Gymnosperms once more abundant. We have already learned that during the carboniferous age the ferns and their relatives were the dominant plants, but fossil remains prove

Fig. 228. Sugar pine bearing the large seed cones

These cones are often over a foot in length. Photograph by King

that seed plants were also present during that time. It was later, during the next age, that gymnosperms became most abundant. There are fossil remains of giant gymnosperms — trees so well preserved that even the nature of the seeds may be determined. In those times gymnosperms were everywhere. The "big trees" and redwoods extended to Greenland, and other groups now well-nigh extinct grew in profusion over very wide areas. Pines did not become abundant until late in the development of gymnosperms, and they are still widely distributed and fairly luxuriant in their growth. No doubt the climate and physical conditions upon the earth have undergone very extensive changes during the earth's history, and in consequence plant life has changed. Therefore the plants now surviving from former abundant groups have probably undergone many alterations since the times when their ancestors were dominant. But they stand as living evidences of the kinds of plants that were most abundant before the last great group became the dominant plants of the earth. That group is the angiosperms.

281. Angiosperms: their diversity. This is the second group of the seed plants and is therefore the highest group of the plant kingdom. Angiosperms exhibit the widest variation in form and in habits of living. As water plants they may be submerged or free-floating, or may grow in water part of the time and on land part of the time; they may grow in regions that are so dry and exposed as to make life seem impossible. They thrive luxuriantly in the tropics, and even live upon the ice in frigid regions. They may live as epiphytes, or as vines climbing upon other plants. They may be parasites, saprophytes, or even carnivorous plants. In form the angiosperms range from diminutive floating disks to gigantic trees. In length of life they range from those that complete their life round many times during one year to individual plants that live to be several centuries old.

The total number of species of angiosperms is not definitely known, but botanists agree that there are over one hundred

FIG. 229. The Southern pitch pine, or long-leaf pine (*Pinus palustris*), which is used as a source of turpentine and pitch

Note the method of tapping the trees to secure the resinous secretion. Photograph by the United States Division of Forestry

thousand species, and some think this number too low. Added to this fact of the large number of species is the fact that the number of individuals of a species may often be enormous, as in the common blue grass, oats, or corn, each species of which consists of unknown millions of individual plants.

The diversity of angiosperms in chemical composition is equally great. Some constitute our most important foods, others produce a large part of our medicines, and others produce substances so poisonous that they are feared by all who know about them.

282. Vegetative structures. The essential facts regarding the ways in which angiosperms make and use their food material have already been given (Chapter II and the following chapters). There have also been abundant discussions to show something of the variety of structures that plants of this group exhibit when they grow under different circumstances, as in the water, on especially dry land, and under extremes of temperature. The ways in which different vegetative structures are used as means of reproduction are presented in chapters on roots, stems, leaves, etc. Reproduction by means of flowers has also received some attention, but a further discussion at this time will serve to connect the angiosperms with the preceding groups.

283. The angiosperm flower. The name *flower* is sometimes used in speaking of the collections of sporophylls that are seen in the cones of pines. In the angiosperms, in addition to sporophylls, there are usually other leaf-like organs around the sporophylls, and the presence of these additional floral leaves is popularly considered as essential to the flower (figs. 9 and 102). These added floral leaves are usually colored, often in very striking ways. There are angiosperm flowers that do not have these added floral leaves, such flowers being naked (fig. 104). No complete distinction can be made between the collection of sporophylls, which in the pines was called a strobilus, and the collection which is commonly known as a flower in the angiosperms.

The essential structures of a flower are *stamens* (*microsporophylls*) and *pistils*, or *carpels* (*megasporophylls*). A carpel, strictly speaking, is one megasporophyll, and when several carpels are united, the result is known as a compound carpel. The name *pistil* is used without discrimination for either a simple or a compound carpel.

The flower and the resulting seed that characterize this group of plants has often led people to give to the angiosperms names which suggest these characters. The most common of these names are *flowering plants* and *seed plants*. The name *phanerogam*, meaning "plants with visible reproduction," was applied when botanists knew less of the intricacies of the reproduction of angiosperms than is now known. In the same way *cryptogam*, which means "plants with hidden reproduction," was applied collectively to the pteridophytes, bryophytes, and thallophytes. These names are still used by many people, but it is evident that an interchange of the names would better fit the facts of reproduction in the groups of the plant kingdom.

284. Stamens and pollen. In connection with the discussion of the gymnosperms the structures of the stamen are fully illustrated (fig. 225). The parts of the angiosperm stamen — the anther and the filament — are similar to the same structures in the gymnosperms, though of course many variations appear. In the young angiosperm anther there are four sporangia, and these, when they ripen their spores, unite in pairs, so that two pollen sacs are formed from the four sporangia (fig. 108). The anthers of the angiosperms may open in a variety of ways, the method of opening being called the *dehiscence*.

Since the pollen grains are formed by the division of cells in a sporangium, it is evident that they are asexual spores. When mature each pollen grain consists of a heavy outer wall, an inner wall, cytoplasm, and nucleus (fig. 118). Often there are starch and oil foods in the pollen grains. The single-celled pollen grain sometimes begins to germinate before it leaves the anther in which it was formed, and when this has

occurred, two cells, and not one, are to be seen within the wall of the pollen grain. The pollen grains must be placed upon the tip of the stigma before further development takes place. The process of proper placing of the pollen grain is known as pollination, to which a chapter has already been given (Chapter X).

285. The pistil. The pistil, or carpel, consists of three parts: the enlarged base, which is called the *ovary*, in which the ovules or developing seeds are borne; the elongated portion above the ovary (the *style*); the tip of the style, usually more or less expanded (the *stigma*). The stigma, when ripe, is ordinarily covered by a sticky fluid which causes the pollen to adhere to it. Through the style the pollen tube grows to the ovules. The ovules may be borne singly or many together in the ovary. They may be attached on the bottom, at the sides, at the top, or on a central axis of the ovary. While the ovules differ so much in their position, there is a general uniformity in their individual structure. The surface of the ovule consists of one or two *integuments*, which at the tip do not quite cover the inner tissue of the ovule. This open tip is the *micropyle*, which means "little gate." Similar structures of the ovules of gymnosperms have already been mentioned (sect. 274). Within the tissue of the ovule is the *embryo sac* (fig. 231). When fully formed the embryo sac incloses seven cells. At the micropylar end of the sac are three cells, the central one of which is the egg, while those at the sides of the egg are the helper cells, or *synergids*. These helper cells may nourish the egg or possibly may assist the development of the entering pollen tube. In the end of the sac opposite the micropyle are the *antipodal* cells, which usually disappear soon after they are formed; and in the central part of the sac is the endosperm cell, which later grows and produces the food or endosperm of the seed.

286. The pollen tube and fertilization. After pollen grains have fallen upon the stigma, the outer wall of the pollen grain breaks, and from the inner wall the beginning of the pollen tube extrudes. The tube tip enters the stigmatic tissue and

forces its way through the central softer tissues of the style. It does not make a passageway by forcing the tissue aside, but by means of its own secretions (*enzymes*) it breaks down these tissues, and they doubtless furnish nourishment to the growing pollen tube (fig. 230). When the tube reaches the cavity

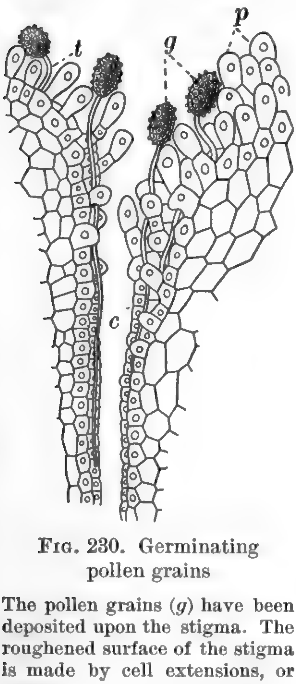

FIG. 230. Germinating pollen grains

The pollen grains (*g*) have been deposited upon the stigma. The roughened surface of the stigma is made by cell extensions, or papillæ (*p*). Pollen tubes (*t*) grow from the grains through the tissue or along the central canal (*c*) until they reach the ovule. Only a small part of the stigma and style are shown in this cut

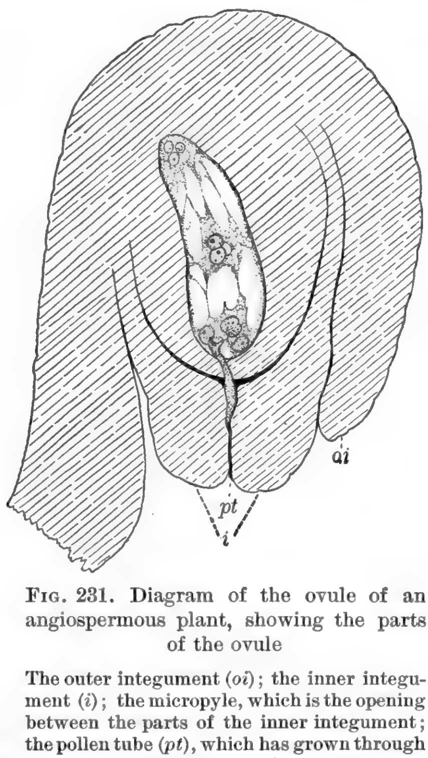

FIG. 231. Diagram of the ovule of an angiospermous plant, showing the parts of the ovule

The outer integument (*oi*); the inner integument (*i*); the micropyle, which is the opening between the parts of the inner integument; the pollen tube (*pt*), which has grown through the micropyle

which contains the ovules, it turns across to the micropyle of the ovule. It then grows through the tissue at the tip of the ovule to the end of the embryo sac (fig. 231). In some cases (elm and walnut) the pollen tube grows down to the base of the ovule, then up through it, and finally reaches the egg.

During the growth of the pollen tube the single cell which at first was in the pollen grain has developed until it now consists of three cells, which are carried near the tip of the tube. Two of these cells are male cells and can serve as sperms, although they are not ciliated. The other cell is a nutritive cell, which goes forward with the tip of the pollen tube and is an important factor in its growth. These cells all pass out of the tube through an opening in its tip when it has reached the embryo sac. One of the male cells unites with the egg cell, and in many cases, perhaps generally, the other male cell passes to the center of the sac and unites with the endosperm cell. The first union of cells is like that of the gymnosperms, but the second does not occur except in the angiosperms. This union of both the male cells with other cells in the same embryo sac is known as double fertilization. After fertilization the egg grows into a new plant, and the endosperm cell grows into the endosperm, or food material, that is stored in the seed around the embryo plant. Double fertilization gives to the seed outside the embryo, as well as to the embryo itself, the characters of both parent plants. In this way, when plants such as different kinds of corn are crossed, the ear thereby produced will have some grains showing the characters of both parents.

287. The new plant. The way in which the fertilized egg grows into the new plant is striking. The egg cell first divides and redivides in such a way as to form a chain of cells. One end of this chain may become elongated and, as the *suspensor*, may attach the developing embryo to the wall of the embryo sac. The cells at the other end of the chain are the ones that produce the parts of the new plant — the stem tip, leaves, and root tip (fig. 232). The embryo in some kinds of angiosperms has but one leaf, which grows at the end, and the young stem is at the side of the embryo. These are the angiosperms with one seed leaf, or the *monocotyledons*. In other cases the embryo may have two (or even more) seed leaves, and the stem is at the tip and the leaves are on the sides of the embryo. These are the *dicotyledons*, or plants with two seed leaves.

While these developments have been taking place in the embryo sac, the integument walls have become dry and hard, so that, by the time the young plant has differentiated the root, stem, and leaf regions, it is usually inclosed by hard and dry walls, and the whole structure is a seed. In some cases the seed is dropped from the parent plant at once, and may begin its growth immediately. Seeds may lie dormant on the ground until the return of spring, or may in some cases lie dormant for several years, and still retain their vitality. The seeds of the cocklebur and of some desert plants may lie in the ground for several years and then grow. The seed coats sometimes become so dry and hard that the water and air necessary for germination cannot penetrate, and this condition remains until, through decay of the wall or through injury to it, the needed materials can get into the seed. Most seeds, such as wheat, corn, and oats, lose their vitality within a few years at the most.

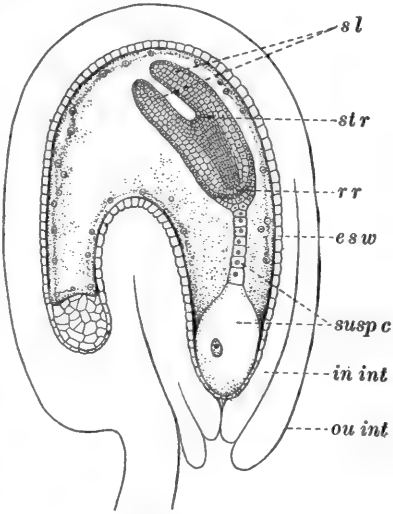

FIG. 232. Diagram of the ovule, embryo sac, and embryo of the shepherd's-purse (*Capsella Bursa-pastoris*)

The parts shown are the outer integument (*ou int*), inner integument (*in int*), embryo-sac wall (*e s w*), suspensor cells (*susp c*), root region (*r r*), stem region (*st r*), and seed leaves (*s l*)

288. The fruit. The relations between seed and fruit are not easily defined, for the reason that the fruit may include a few or many structures. The ripened ovule containing the embryo is the seed. Sometimes structures other than the seed ripen with it; regardless of how many things ripen with the seed, all are included in the term *fruit*. In the sunflower the

ovary wall ripens as a close-fitting, thin coat about the seed, and the kind of fruit thus formed is called the *akene.* In the stony fruits, as in the peach and apricot, the ovary wall divides; the inner part produces the hard covering about the seed, and the outer part produces the pulpy flesh. In the apple the calyx is joined to the wall of the ovary, the seeds are inclosed in the ovary cavities, the ovary wall ripens, thus becoming the core of the apple, and the calyx ripens into the greater part of the fruit. A transverse or a longitudinal section of an apple or pear will usually enable one to determine what part of the fruit is the ripened calyx and what part is the ovary wall.

In some cases whole clusters of flowers and the modified portions of the stem upon which they grew may ripen into a single fruit; or the pistil may grow while the seeds are developing, as in the beans and peas, so that the ripened pod is hundreds of times as large as the pistil was when fertilization took place.

The distribution and germination of seeds was fully discussed in previous chapters, and if those chapters are briefly reviewed at this time, it will be found helpful.

289. Evolution of plants. The four great divisions of the plant kingdom, and the most important classes of these divisions, have been discussed. It must have been apparent to most students that constant increase in the complexity of plants was encountered as we passed from lower to higher groups. This increase in complexity appears in the nutritive parts of plants and in the parts that have to do with reproduction. The process of gradual development from simple to complex is the process of evolution. Indeed, there may also be evolution in the opposite direction, as occurs when, through long and constant changes, simple forms are derived from complex ones. Usually evolution is thought of as having to do with increase in complexity rather than with decrease. The oldest plants of the earth were very simple, and from them, in one way or another, more complex ones have developed. The simplest plants that are now living have doubtless

changed greatly from the oldest simple plants. While, therefore, we compare one living group with another, we must keep in mind the fact that a higher group of living plants has not necessarily developed from one of the lower living groups, but rather that in past ages a common ancestry gave rise to both. The lower group has probably changed less than the higher one. It is like two streams of water that have their source on the top of the same mountain; though their source is essentially the same, the conditions under which they flow may make the two rivers quite unlike when they reach the valleys below.

290. Brief summary of the groups.[1] The thallophytes consist of simple plants, some of which (the algæ) possess chlorophyll, by means of which they manufacture their own foods. Other thallophytes (the fungi), being without chlorophyll, cannot make their own foods and are dependent. Dependency is expressed in types of parasitism and saprophytism, which are often of importance to other living things. These simple plants are prostrate and are not differentiated into roots, stems, and leaves. While reproduction is simple in this first group, in some plants we find specialized sex organs, with sperms and eggs for the formation of sex spores.

In the bryophytes the moss exhibits a much more complex type of plant. It has an alga-like stage; then it sends up leafy shoots, which expose chlorophyll to the light in a better way than appeared in the thallophytes; these shoots also bear highly differentiated sex organs. From the sex spore there grows a special asexual spore-forming stalk and capsule, from

[1] No attempt is made at this time to give a complete summary of all the important characters of the groups studied; the aim has been rather to state only the most important things which will cause each group to stand out with some individuality and at the same time give it some relation to the series of groups as a whole. Neither is any attempt made in this book to present the evolutionary series of plants. The groups are presented so that the increasing complexity is apparent, but the close evolutionary connections are omitted, and the emphasis that is sometimes placed upon evolution is here placed upon securing an elementary idea of the kinds of common plants that are found in each of the great groups.

which many asexual spores are formed. In both reproductive and nutritive work the bryophytes are much more complex than the thallophytes.

The ferns have woody tissue and often have immense leaves and are well equipped to do chlorophyll work. They often store in one year food which serves in part for the growth of the next year. Asexual spores are formed in great numbers by means of highly specialized sporangia. These spores, when they germinate (as in the case of the ferns studied), produce chlorophyll-bearing, independent plants, which grow in obscure places and produce sex organs by means of which sex spores are formed. From the oöspores new leafy fern plants grow.

In the spermatophytes we have the most important and most prominent plants of the earth. They have vegetative structures that are very much more complex than are those of any of the preceding groups. These vegetative structures are so widely differentiated as to meet the demands of almost any conditions. The flower and the seed are special reproductive structures which, with successful vegetative structures, seem to have given these plants their position of ascendancy in modern plant life.

291. Classification. Throughout this book many illustrations of the seed-plant group of the plant kingdom have been used. Although but a few of these illustrations are cited here, enough are given to enable the student to relate the classification of spermatophytes to that of preceding groups.

GROUP D. SPERMATOPHYTES

- CLASS I. GYMNOSPERMS. Genera used as illustrations — *Pinus* (pine), *Picea* (spruce), *Juniperus* (juniper), *Sequoia* ("big trees" and redwoods)
- CLASS II. ANGIOSPERMS
  - SUB-CLASS I. MONOCOTYLEDONS. Genera used as illustrations — *Lilium* (lily), *Zea* (corn), *Triticum* (wheat), *Avena* (oats), and many others
  - SUB-CLASS II. DICOTYLEDONS. Genera used as illustrations — *Quercus* (oak), *Capsella* (shepherd's-purse), *Pyrus* (apple and pear), *Rosa* (rose), and many others

PROBLEMS

1. In what ways are the seed plants the most complex of all plants?

2. What different kinds of structures in various seed plants may remain dormant throughout drought or winter, and later continue the growth of the individual plants to which they belong?

3. Show ten ways in which the seed-plant habit of storing food in seeds and elsewhere is important to industries. What four plants are most valuable for their stored food?

4. What plant products are being used as substitutes for animal products, as cottolene for lard, etc.? Are there good reasons against such substitution?

5. How may man vary the amount or quality of food stored in plants?

6. What cases are there in which man has varied plants until they would probably be unable to maintain themselves in nature if unprotected?

7. What is meant by the statement that the angiosperms are the youngest and most successful group of plants?

CHAPTER XIX

PLANT INDUSTRIES

292. Origin of plant cultivation. In the various chapters of this book we have constantly recognized the relation of plants to the common interests of men. It is important, however, that special uses of plants in the industries should receive separate attention.

In the early stages of civilization plants were used by men for food, clothing, and fuel, for the construction of houses and boats, and in many other ways. In order to obtain those plants that would best serve any of these uses, some observation and experiment with plants doubtless had to be made. Indeed, primitive people are often well versed in the nature of wild plants, so that they know what to select and where to find the desired plants in the seasons when they are available. Wild plants that were good for food or possibly for medicines were cared for early in the history of civilization. We can only guess at the ways in which they were first watched and protected, but they were cared for by people who foresaw a need for the products of these plants when mature. With such activities as these agriculture came into existence. At this time comparatively little was known of the nature of plant life, and therefore early agriculture was relatively simple. As more has been learned about plant life, plant products have improved in quality or in quantity, or in both. As populations become more dense, greater demands are made upon plants as a means of supplying adequate food and clothing.

293. Problems of plant industries. Each of the plant industries involves two kinds of problems. First, there is the problem of carefully applying what science has already discovered

about the growth of plants. This requires a knowledge of the facts that are known about the structure of plants, the conditions of soil, temperature, moisture, etc. under which they thrive best, the nature of plant and animal diseases and the means of preventing them, and the best methods of utilizing plant products after the plant has made them. Second, the life of a plant, like that of an animal, is a very intricate matter, and there are many highly important questions upon which science as yet has little positive knowledge. Each plant industry, therefore, involves many unsolved problems, about which we need to secure additional knowledge. Thus, science has discovered what kind of cultivation will best enable the corn plant to thrive; but, although botanists know the life cycle of the smut which attacks corn, a practical and thoroughly effective way of preventing the attack has not yet been found.

294. The sugar industry. Nearly all plants that do the work of photosynthesis produce sugar of some kind. In some plants the amount produced may be extremely small, and it may remain as sugar only for a brief period before it is made into some other compound and assimilated into living substance or stored within the plant. In other plants the amount may be large, and may be retained as sugar for long periods. It may be stored as sugar or, more often, as starch, which is usually changed to sugar again for transference through the plant. Plants of the latter class may prove useful in the sugar industries. It is possible that wild plants may yet be found that are valuable for this sugar content, but at present a few species produce the sugar of the world. The sugar maple (*Acer saccharum*) (fig. 233) has long been used as a source of sugar. Other species of the same genus produce sweet sap, but not so abundantly as the sugar maple. The tree belongs to the type of primeval forest that prevailed in the north-central and northeastern parts of North America. In early spring the previous season's surplus of sugar is transported to the parts of the tree where, a little later, there is active growth of new leaves. This stored sugar is used in

the early spring growth of new parts of the plant or in replenishing old parts, or may even be retained until another year. The passage of sugar-laden sap is through the youngest fibrovascular bundles. By boring a hole through the dead bark into this region, sap may be withdrawn. When it is secured in sufficiently large quantities, the water may be evaporated from it until thick sirup or sugar remains. Ordinarily

Fig. 233. Sugar-maple trees which have been tapped every year for over eighty years

The trees are tapped by boring into them so as to reach the sapwood; then a tubular spile is driven into the hole, and a bucket is suspended upon a hook on the spile. In this way the sap is caught in the bucket

a good sugar-maple tree produces 15 or 20 gallons of sap in one season, though this amount may be greatly exceeded by especially good trees. The percentage of sugar in the sap varies widely in different seasons and between different trees in the same season, but usually it is from 2 to 3 per cent. Individual trees produce in one season from half a pound to 7 or 8 pounds of sugar. Maple sirup is the partially evaporated

maple sap and, as ordinarily used, it contains from 30 to 40 per cent of the water originally in the sap.[1]

The sugar-making season is short, because, as soon as new protoplasm is developed in great abundance, the sap no longer makes acceptable sugar. Maple trees may be used from year to year indefinitely without apparent injury due to the withdrawal of sap, but the stem may be weakened by too frequent boring at one level, and the wound, though it heals in one or two years, may serve as a place of entrance for disease organisms.

Fig. 234. A Cuban sugar-cane field

Standing cane is seen at the left, between the men and the trees; in the foreground the men are loading sap-laden stalks upon the carts. Note the heavy soil covering of leaves that have been stripped from the sugar-cane stalks

Sugar-maple groves are being planted in some places for the sugar product, but other plants of more rapid growth and larger sugar production will doubtless prevent maple sugar from entering largely into sugar consumption. The distinctive flavor of maple sugar and sirup, however, will enable it to continue as a highly desired article of commerce.

[1] "The Maple Sugar Industry," *Bulletin 59*, Bureau of Forestry, U.S. Dept. Agr., 1905; "Maple Sap Sirup," *Bulletin 134*, Bureau of Chemistry, U.S. Dept. Agr., 1910; "The Production of Maple Sirup and Sugar," *Farmers' Bulletin 516*, U.S. Dept. Agr., 1912.

About one third of the world's supply of sugar comes from the sugar cane (*Saccharum officinarum*), which has at least a dozen varieties that thrive in tropical and sub-tropical countries (fig. 234). This plant has a very heavy root system, from which several stalks grow. Its leaves are large and numerous, so that much chlorophyll work is possible; hence much sugar may be made by the plant. The stalks when full-grown are so well filled with sugar-laden sap that natives often use them directly as food. The sap from good cane may contain from 17 to 18 per cent of sugar. After the leaves are stripped off, the stalks are cut and the sap is pressed from them by means of machinery specially designed for that purpose; after this the water is removed from the sugar by evaporation. Some sugar cane is grown in this country, but sorghum is more widely distributed and produces a sirup that is extensively used.[1]

Sugar beets (*Beta vulgaris*) have been grown in Europe for many generations, but it is only in recent years that they have been widely grown in the United States. They have already become a prominent factor in the sugar industry. Sugar beets thrive in temperate climates, mature in a relatively short season, and grow well in a wide range of soil conditions. Besides these advantages, they are very productive. The sugar produced from beets is rapidly coming into general favor.[2]

295. Fiber plants. Primitive people learned to use the strong-fibered grasses and the tough bark of some trees in making bands and cords for tying various articles. Leatherwood, or moosewood (*Dirca palustris*), and Indian hemp (*Apocynum cannabinum*), often so used by the early settlers in this country, have fibers of very great strength, which, when dry, are almost as strong as leather thongs. The making of cordage from plant fibers has become an important industry. Many grasses, palms, hemps, etc. have extremely long, strong fibrovascular bundles, which, when removed and twisted together, make twines of

[1] "Sugar Cane in Porto Rico," *Bulletin 9*, Porto Rico Agr. Exp. Sta., 1910.
[2] "The Sugar Beet," *Farmers' Bulletin 52*, U.S. Dept. Agr., 1910.

great strength. The banana leaf and stem and the pineapple leaf produce some of our most highly valued fibers for cordage. These and many other fibers may be woven into mats or cloth, and some of the finest dress goods and fancy articles are made from pineapple fiber (*Ananassa sativa*). Doubtless the long list of plants known to produce valuable cordage fibers and materials for weaving might be added to materially by a thorough study of our wild plants.

The most important fiber plant is cotton (several species of *Gossypium*).[1] Some of its varieties are grown in almost every tropical and sub-tropical country, and as a source of income it is to our southern states what corn is to the central states, and wheat to the northwest. Within the seed pod of cotton the seeds are surrounded by long white fibers which are the most valuable portion of the plant. Other parts of the plant have great value, however, since the seed yields oil and meal and the stem of the plant yields fiber and cellulose which is manufactured into a long list of commercial products. As an agricultural plant cotton presents its own set of problems related to soil, moisture, cultivation, and diseases, and some of these problems are just beginning to be solved. It is doubtful if any other staple crop has such great possibilities of immediate increase through scientific study of its growth and productivity.

In temperate regions the hemp plant (*Cannabis sativa*), flax (*Linum usitatissimum*), and jute (*Corchorus capsularis*) are much grown for their fibers. In tropical countries *manila hemp* is made from fibers in the leaves and stems of one of the bananas (*Musa textilis*). *Sisal* is made from the leaves of a century plant (*Agave rigida*). Two varieties of *Agave rigida* are cultivated for this use, and several other varieties are used locally wherever they grow wild. The list of plants producing valuable fibers is a long one, and those given above are merely the leading ones.

[1] "The Cotton Plant," *Bulletin 9*, Vol. 27, N.C. Agr. Exp. Sta., 1906; "A Profitable Cotton Farm," *Farmers' Bulletin 364*, U.S. Dept. Agr., 1909.

The manufacture of paper and many articles of commerce from wood pulp has become an industry of such prominence as to endanger the supply of the softer timbers from which the pulp is made. Straw and cornstalks are sometimes used in making paper.

296. The grasses. Grasses contribute to industries already mentioned and others yet to be discussed, but in this connection we have in mind those grasses that are used directly or indirectly as food for domesticated animals. The significance of pasturage can be seen by any one who observes the use made of grasslands on any farm or ranch. Grasses furnish the chief or entire food supply for most domesticated animals throughout spring, summer, and autumn, and during winter dried grasses (hay) and the grain from grasses complete the food supply. Wild grass has been depended upon extensively, but agriculturists have found that grass production and hay crops improve as readily under scientific management in a state of domestication as do other crops. Native wild grasses, uncared for, often produce but a small percentage of the pasturage or hay that selected grasses (as blue grass and timothy), when properly planted and cared for, may produce.[1]

297. The cereals. The grain-producing members of the grass family, as wheat, oats, corn,[2] rye, barley, and rice, are the chief agricultural plants of the earth. The wild ancestors of some of these cereals are known, as in the case of wheat, oats, and rye. In some cases, as wheat, our present cultivated types do not differ widely from the ancestral types in size of heads or grains, but they differ enormously in the range of territory over which they are grown and in the amount grown on any single unit of area. In extending the range of any plant beyond its native growing place new problems arise, such as adapting the soil to it and preventing the plant and

[1] "The Improvement of Mountain Meadows," *Bulletin 127*, Bureau of Plant Industry, U.S. Dept. Agr., 1908.

[2] E. M. East, "A Chronicle of the Tribe of Corn," *Popular Science Monthly*, **82**: 225–236. 1913.

animal enemies that the plant may encounter in its new growing place. Thus when corn, which naturally thrives best as a tropical or sub-tropical plant, is grown in the north central states, the shortness of the season may not allow time for ripening the ear; but by experimentation certain varieties of corn have been discovered or developed (see chapter on Plant Breeding) in which the plant is not so large as the average, and the ear, though somewhat smaller, matures in less time. Some kinds of seed corn are advertised by the salesmen as "ninety-day corn," which means that the plant will grow and ripen a new ear within ninety days, while in case of some other varieties of corn more than double that time is required for it to mature. Furthermore, in the case of wheat some varieties are much less readily affected by the rust diseases than are other varieties; some thrive best in certain regions when planted in the late autumn (winter wheat); and others in other regions thrive best when planted in early spring (spring wheat). Every civilized or even partially civilized nation depends largely upon one or more of the cereals, and in spite of the fact that the nations have been dependent upon them for so long, the practices relative to selection of seed, cultivation, prevention of diseases, and utilization of the products have changed very little from decade to decade. The application of scientific principles to the production of cereals has already shown great possibilities of improvement in plant production, but only the most intelligent agriculturists utilize these investigations, the traditional "practices of the fathers" often dominating the majority of those who till the soil. No doubt the decades immediately to follow will bring much new scientific knowledge about the growth of cereal crops, and nothing seems more fundamental than the application of those sciences which may lead to a more effective production of the world's food supply.

298. Horticulture. Fruits and berries have constituted a considerable part of the food of men throughout the period covered by history. Wild apples, grapes, and berries, in nearly

all temperate regions, have been and are still extensively used. But selection and improvement from these wild ancestors have given us varieties greatly superior to the wild types. Even to-day, however, there are many people who plant fruit trees and act as if they believed that the tree should live and produce as an essentially wild plant. The plants which are the basis of horticulture have many things in common with all other plant life. They must have suitable soil and moisture, proper exposure to the light, freedom from destructive enemies, and proper cultivation, else they cannot manufacture their own food material and the fruit which men want to produce. Most of the soil of the United States is good for horticulture if men will do the things necessary for proper production of fruit. Distant regions may for a time seem attractive to fruit growers, on account of their freedom from diseases, but diseases eventually enter even these distant regions and affect the crop. Migration to new territory is not nearly so important in fruit growing as a thorough study and application of the science of horticulture.

FIG. 235. An old grafted apple tree

This illustrates an old and well-nigh discarded method of stem grafting. The stock is much larger than the scion, owing possibly to imperfect union of tissues and possibly to difference in normal rate of stem thickening. The absence of proper care in pruning this tree is a feature too often seen

Grafting has long been practiced in horticulture (sect. 87). Parts of two individuals of closely related plants may be made to unite their woody tissues and grow as one plant. If one has a particularly desirable variety, he may insert small branches (scions) from it upon other less valuable related stock plants. The growing tissues (cambium) of the two, if united, will enable the pieces to grow together and continue to live essentially as one plant. In former practices the grafts were usually made aboveground and were probably made less effectively than they are now. If one visits an old orchard he is likely to see evidence of these grafts on the main stem or on the branches of old trees (fig. 235). The difference in size of stock and scion in old grafts may be due to a difference in the natural rate of thickening of wood in the two, or to imperfect joining of tissues, which causes a lodgment of food material and a consequent unusual growth on one side of the graft. The advantages of grafting are great. Vigorous plants which produce poor fruit or scanty fruit may be used in extending the production of especially prolific plants that produce fruit of unusually good quality. The same general principles apply to the culture of flowers as to fruit culture, and the possibilities are equally great.

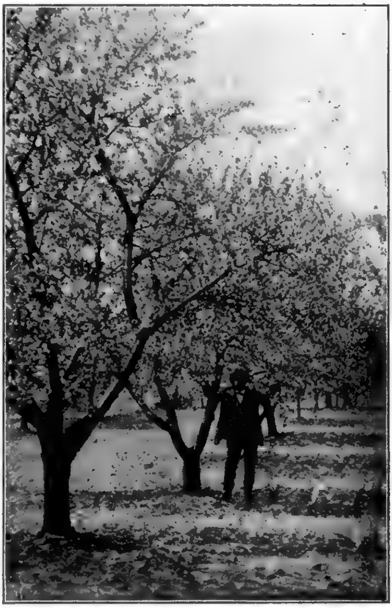

Fig. 236. A properly pruned cherry tree, the remaining branches full of flowers

Photograph by the Michigan Development Company

Pruning has been found to increase both the quality and the quantity of fruit. Sometimes it is done solely for increase in quality, as when all but one or two buds of a chrysanthemum or tomato are removed, so that all the strength of the plant is thrown into the development of one or two specimens of great size and beauty. In fruit orchards it has been found that the removal of the old or surplus branches stimulates the production of flowers and fruit. There are many orchards of good vigorous trees which might be made productive simply by pruning (see figs. 236 and 237). Pruning properly done not only stimulates the production of fruit but also helps to keep the tree in such form that the load of fruit will be supported and easily gathered when mature. In pruning dead and living branches care should be taken to prevent the entrance of organisms that induce decay. A coating of paint or of tar upon the fresh wound usually prevents infection, but old wounds need to be cleaned out, sterilized, and filled with cement.

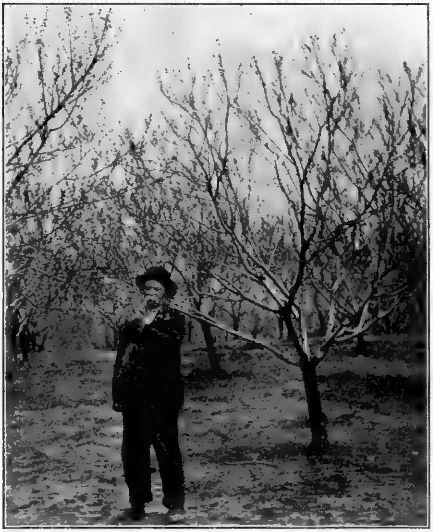

FIG. 237. A well-pruned peach tree just past the flowering period

Photograph by the Michigan Development Company

Spraying to remove or prevent disease is an important branch of horticulture; fruit and berry plants are subject to an increasing number of diseases, both plant and animal in their nature. The subject of sprays and spraying is too extensive for discussion here. It must be remembered, however,

that a tree or a bush filled with a large amount of perfect fruit or berries is not a usual occurrence in nature. Horticulture attempts to use the plant as a machine for producing a large amount of perfect fruit; to secure this result we must make careful use of every known agency that will help the machine to work well and that will protect it from those things that in nature would injure it or reduce the value of its product. The state agricultural experiment stations publish instructions for spraying orchard and garden plants.

299. Gardening. Gardening has to do in the main with the production of plants whose growing parts men use for food. The list of plants thus used is a long and constantly increasing one, and although the gardening industry is extending rapidly, it is not keeping pace with the increasing demands for its products. Both vegetable and flower gardening have problems distinct from those of other plant industries. Both are highly intensive in their nature and present new problems in such matters as soil selection and replenishment, cultivation, harvesting, marketing, and the prevention of disease.

Wild plants of many kinds are used as medicines, and some of these are grown in large quantities in gardens especially designed for that purpose.[1]

300. Plants and the soil. The plants that constitute the basis of plant industries depend in large measure upon their relation to the soils in which they live. Soils are very different from one another, some by their nature prohibiting the life of certain kinds of plants and making possible the growth of others. Some of the facts about differences in soils are known, others are matters of vigorous argument between scientists, and still other problems are recognized by all as still wholly unsolved. That the structure of the soil has much to do with its appropriateness for plant life is generally recognized. Our coarsest gravelly soils consist of much rock

[1] "Wild Medicinal Plants of the United States," *Bulletin 89*, Bureau of Plant Industry, U.S. Dept. Agr., 1906; "American Medicinal Leaves and Herbs," *Bulletin 219*, Bureau of Plant Industry, U.S. Dept. Agr., 1911.

material, with a minimum amount of decayed material from plant and animal life. If the water level is below such soils, the water runs away and there is left in the soil little available moisture and little available organic matter. In sandy soils the rock has been broken by weathering processes, sometimes aided by the action of plant life, until the rock particles are small. The coarseness of the sand depends upon the extent to which the rock particles are broken. They may have been crushed and worn into pieces so small that clay is formed and the separate grains can be seen only by magnification.

Water may be in the soil either in the spaces between soil particles or adhering to the particles. As the soil becomes finer its ability to retain water increases. This is due to two facts: first, that water adheres to the surface of the soil particles; second, that the larger the number of particles within a given volume the greater is the surface exposed.[1] Also, soil with fine-grained sand will hold the products of decayed plant and animal life better than rocky soils. Soils are classified into many kinds, according to the size and nature of the rock material and the nature of the plant and animal material contained. The leading kinds are *gravelly soils*, containing small pebbles which usually show by their form and sometimes by their markings the kind of treatment they have undergone; *sandy soils*, in which the rock material is more uniform and has gone farther in its reduction; *clay soils*, whose particles are so small and fit together so compactly that the rock origin is not very evident; *peaty soils*, containing comparatively little rock material but much more of the products of partial decay of plant and animal bodies. There are all possible gradations between these different kinds of soils. The chemical and physical nature of the rock-and-humus content of soils has much to do with their relation to plant life.

[1] This may be shown by calculating the surface of a cube ten inches in diameter, then cutting it into one-inch cubes and calculating the surfaces of these, and then comparing the surface of the original cube with the sum of the surfaces of those made from it.

301. Water drainage. The amount of water in the soil varies and depends upon many factors. The coarse soils (gravel and coarse sand) soon become dry when there is little rainfall and no replenishment of water from below. Fine-grained soils which contain a good supply of organic matter may become filled with water and may retain this water for a long time. They may become so filled with water as almost entirely to exclude the air of the soil, thus suffocating the roots of plants. But some air remains in all soils, even below ponds and streams, and some water plants can live with their roots in such water-logged soils. From 50 to 60 per cent of the total water-holding capacity of soil is found to be best for the growth of cereals. Our agricultural plants, except rice, cannot endure water-logged soils, and drainage has often been necessary to bring about a more favorable water-and-air content of cultivable lands.

Natural drainage may be either on the surface or underground. It is evident that in cultivated soils extensive underground drainage will in times of heavy rains hasten the removal of surplus water and at all times will facilitate better aëration of the soil. The annual rainfall in the United States varies from ten inches or less to more than sixty inches per year, and when any considerable part of this rainfall comes in a short period of time, non-enduring plants will suffer and sometimes be drowned unless adequate drainage is supplied.

North America still has immense tracts of waste swampy land that only needs drainage and tillage to make it highly productive soil. It is estimated that the United States has nearly 100,000,000 acres of swamp land, much of which is drainable, and in many places trained engineers are devising the needed drainage systems, and the land is being reclaimed.

302. Influence of cultivation on water supply. In earlier times agriculturists advised against cultivating corn and other crops during times of drought, because they thought that, if constantly stirred, the soil would lose its moisture more rapidly.

People now know that it is of the greatest importance to till the soil during droughts, in order that it may not lose its moisture. An illustration will help in understanding this. If two pieces of loaf sugar are placed one upon the other, the lower one held in the thumb and finger and the other left lying loosely upon the first and not touching the fingers at all, and if the lower one is then placed in contact with water, two important facts are shown: The lower piece takes up water freely, but the upper one, though lying upon the lower wet piece, becomes wet only after a long time. Close connection between the solid particles is necessary for the rapid upward passage of the water.

When soils are compact, moisture from the deeper portions passes upward freely, as in the lower lump of sugar, and evaporates into the air. If, however, the surface is kept loose and finely pulverized, so that the particles are less closely connected, moisture does not readily pass through it, and there is not so much loss from evaporation. The roots of plants, being more deeply placed, are in contact with the moist soil from which a supply of water may be secured. The depth to which roots are known to go in regions where the water is found only at great depth is discussed in section 22.

It has been generally supposed that tilling the soil serves the twofold purpose of regulating the moisture supply for growing plants and of preventing the growth of weeds. Experiments upon the cultivation of corn seem to show, however, that if all the weeds are removed without disturbing the soil, the yield is practically the same as when the soil is tilled.[1]

303. Dry farming and irrigation. In regions with a very scanty rainfall frequent tillage of the surface seems to enable the soil to hold most of the water that falls, and in this way a crop may be grown, sometimes every season and sometimes every second season. Evidently much work is necessary to enable the soil to accumulate enough moisture to supply the needs of

[1] "The Weed Factor in the Cultivation of Corn," *Bulletin 257*, Bureau of Plant Industry, U.S. Dept. Agr., 1912.

a crop.[1] It now seems probable that certain drought-resisting plants, as some kinds of wheat,[2] will make it possible to use soils which have not been usable because of inadequate moisture.

In regions where available water supplies exist, irrigation is practicable. Between 15,000,000 and 20,000,000 acres of land are said to be under irrigation in the United States, but this area is small compared with the large extent of our so-called desert lands, which only need water and proper cultivation to make them highly productive.

304. Effect of living things in the soil.[3] Microscopic plants and animals of many kinds and in great numbers live upon one another, upon plant roots, or upon dead organic matter in the soil. The roots of living plants, the molds, and the burrowing animals, such as the larvæ of insects and the earthworm, constantly take from, add to, or otherwise change the soil. Earthworms eat their way through it, and as they do so they make it more porous and excrete materials that add to the soil's available organic matter. Certain groups of soil bacteria have already been discussed (sect. 191). The living things of the soil may be said to constitute an extensive and intricate group of plants and animals living close together and greatly affecting the nature of the material in which they live. Some of the products of the soil inhabitants are helpful to agricultural plants and some are harmful.

305. Quality of soil and growth of plants. A comparison of plants of the same kind that have grown in different regions readily shows that soils differ widely in their ability to support vegetation. Even the different parts of the root system of one plant illustrate this fact (fig. 238). Soils that are at one time fertile may lose that fertility, as may be seen in any farming region. Many studies are being made, to determine how fertility is lost and what will restore it, and while the question

[1] "Dry Farming in Relation to Rainfall and Evaporation," *Bulletin 188*, Bureau of Plant Industry, U.S. Dept. Agr., 1913.

[2] Native wheat which is thought to be primitive has been found growing wild in arid districts in Palestine.

[3] See Marshall, Microbiology, P. Blakiston's Son & Co., Philadelphia.

is not settled, notable experiments that have been carried on at the experimental station at Harpenden, England, since 1848 will show the nature of some of these studies. Certain crops have there been grown year after year upon the same soil. A barley field which has been unfertilized since the experiments began, produced, in the year 1849, a little over 40 bushels per acre. Each year thereafter, with no fertilization,

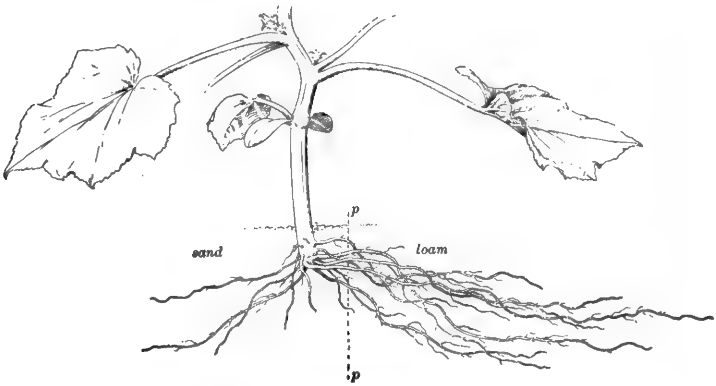

Fig. 238. Effect of quality of soil on growth of roots

The cucumber plant shown in the figure was grown in a shallow box, one end of which was filled with sand and the other with rich loam. The seed was planted in the sand, quite near the partition (p) of mosquito netting which separated the sand from the loam. When the plant was one foot high, the earth and sand were washed away and the roots sketched. Those grown in the loam weighed nine times as much as those in the sand. Three eighths natural size

barley has been grown on the same field, and the yield has steadily decreased, so that during the twenty years ending with 1909 the average per year was less than 15 bushels per acre. Another piece of ground was used for wheat, turnips, and clover in rotation (with three years given to each rotation), and was fertilized by the use of nitrogen and mineral fertilizers. Considering only the wheat records, we have the following: In the first twenty years the average yield of wheat for the years in which wheat was grown was 35.3 bushels per acre; in the second period of twenty years 32 bushels per acre was

the average yield; and in the third period of twenty years the average yield was 36.4 bushels per acre. In the second twenty-year period one year of general wheat failure materially reduced the average for that period.

The benefits that are derived in plant industries from rotation of crops are universally recognized by scientific students of the matter, but the explanation of the results secured furnishes material for active discussion. Within the last decade it has been shown [1] that at least some cereals excrete and leave in the soil substances that are injurious to the kinds of plants which produced them. These plant poisons may be the cause of loss of fertility of soil, or loss of fertility may be due to the fact that the soil has been exhausted of the available materials needed in the growth of plants. Soil replenishment through use of fertilizers may possibly bring in a new supply of available materials, may neutralize or counteract the injurious excretions within the soil, or may merely change the physical nature of the soil so as to make it more favorable to plants. Whatever the scientific explanation, the great value of natural fertilizers and of rotation of crops in replenishing soils is evident to any practical student of soils.

306. Loss of soils. In some places the chief danger is not primarily that of loss of fertility, but loss of the soil itself. It may be washed or blown away or removed by fire. If a pane of glass that has been moistened with oil is exposed for a time to the wind on a dry day, and then examined with a strong magnifying glass, it will furnish a good demonstration of the dust-carrying power of moving air. Windowpanes in the houses near the end of Cape Cod finally become translucent, like ground glass, from the action of sand driven by the wind. When cultivated fields become dry, the wind may carry away large quantities of soil.

[1] O. Schreiner, and H. S. Reed, "Some Factors influencing Soil Fertility," *Bulletin 40*, Bureau of Soils, U.S. Dept. Agr., 1907; also "The Production of Deleterious Excretions by Roots," *Bulletin 34*, Torrey Botanical Club, 1907.

Rapidly running surface water often carries away part or all of the fertile soil.[1] In grasslands, meadows, and forested areas surface water is retarded in its rate of flow, and consequently does not carry away much soil. In regions that were once forested and from which the timber has now been largely

FIG. 239. Erosion of the soil following removal of the forest

This land was covered with a heavy pine forest and had a rich soil, which was held upon the forest floor. When the timber was removed, erosion soon cut ditches through the pasture land, and part of the rich soil was washed away

removed, the surface water soon erodes ditches (fig. 239), which, with rapidly deepening channels and developing tributaries, will in a few years carry away much of the fertile soil of the forest floor. After forest fires, which themselves destroy much of the humus of the forest soils, the surface water, which is no longer retarded and absorbed by humus, flows

[1] "Soil Erosion," *Bulletin 71*, Bureau of Soils, U.S. Dept. Agr., 1911.

with increased rapidity. In so doing it carries away large quantities of soil, sometimes uncovering the burned roots until the trees are easily overturned by winds.[1]

There are several means of preventing much of this loss of soil by erosion. In wooded regions judiciously cutting part of the timber each year, rather than cutting all of it at once, gives opportunity for new plants to occupy and hold the soil. There are many kinds of soil-holding plants which, if properly placed, will prevent erosion in its earliest stages, and these should be used. In open, hilly fields which are exposed to erosion, grass and meadow crops are desirable, since their roots help to hold the soil throughout the whole year. In such cases the roots and stems help to prevent the rapid run-off of the surface water. The very things that need to be done in the cultivation of plants increase the danger of loss of soil where rapid flow of the surface water cannot be prevented.

In hilly fields it is often difficult, sometimes impossible, to prevent erosion. In some localities the rows of growing plants are arranged across the slope of the hill; this arrangement helps somewhat in retarding the surface flow of water. If cultivation is continued in such places, the soil sooner or later becomes eroded, and it is with extreme difficulty that any plants gain a foothold (fig. 240). In some foreign countries hillsides have been saved for cultivation by a process of terracing. The terraces are constructed in such a way that the soil upon each is level or slopes toward the hill, thus retarding or preventing erosion. Such terraced farms are sometimes most desirable for vineyards, but it is obvious that for ordinary crops these elaborate processes of terracing, and the constant care required, will prove profitable only where available land is extremely scarce. In many localities where the slope of the surface is moderate enough, underground drains may be laid to take care of the surface flow and thus prevent erosion except at times of extremely heavy rains.

[1] "The Movement of Soil Material by the Wind," *Bulletin 68*, Bureau of Soils, U.S. Dept. Agr., 1911.

307. Air and temperature. In the earlier sections of this book the air relations of plants have been presented in the various discussions of photosynthesis and of plants of different regions. Under most circumstances the air is likely to contain enough of the proper gases, and not too much of harmful ones, to enable plants to thrive. In large cities and in the vicinity of manufacturing establishments, especially smelters, harmful gases are present in quantities that often kill plant life. For fifteen miles or more about certain copper smelters all plant life has been killed. In commercial greenhouses and in homes the plants may exist in the presence of illuminating gas, but 1 part of illuminating gas in 80,000 parts of air will prevent carnations from flowering, and other plants are prevented from flowering and often killed by such gases.

In the vicinity of cement manufacturing plants the cement gets into the stomata of the leaves, becomes hard and closes the stomata, and eventually results in killing all plant life.

308. Prevention of plant diseases. The development of plant industries has tremendously stimulated the study of plant diseases. Many volumes have been written upon the topic, and every agricultural experiment station issues bulletins from time to time, to advise people about the latest discoveries in regard to the nature of important diseases and the means of preventing them. The ways in which these diseases operate are various. They may use the food material made by the host plant, as is supposed to be true in case of wheat and oat rusts; they may also consume or supplant important tissues, as when corn and oat smut occupy the grains of their hosts; they may stop the vascular tissues, as is the case with the bacteria that produce the brown wilt of cabbage and other related plants; or they may excrete substances that are poisonous to the host plants.

Diseases due to animals such as plant lice or aphids, scale insects, and larger insects are extremely destructive. The intricate nature of such diseases may be shown by using as an illustration the aphids that often produce serious injury

FIG. 240. A hillside which once was forested but is now washed into gullies and ridges

Not enough plants have gained a foothold to prevent erosion. Photograph by United States Forest Service

to corn. Their nourishment consists of the juices which they suck from the tender roots. They excrete a sweetish substance called honeydew, which is used as food by ants and sometimes by other kinds of insects. The aphids may begin to live upon corn when the seedling is germinating, and continue upon the growing plant until it is mature. The aphids are sluggish insects and, although they reproduce rapidly when food is abundant, they are not readily able to pass through the soil or over its surface to the roots of new plants.

There is a common black field ant which devours the honeydew, apparently with great relish. The burrows of these ants may often be seen about the bases of corn plants. They dig tunnels to the roots of the corn, then carry down some of the aphids and place them upon the roots. There the aphids are cared for by the ants, and the latter secure the honeydew as food. Throughout the summer and autumn the ants constantly care for the aphids and their young. Aphid eggs are carried to the places that are most favorable for their hatching, and when the young are hatched they are transplanted upon tender young roots. When disturbances of the soil threaten destruction to the eggs, the ants seize them as they would their own eggs and carry them away. At the beginning of the winter aphid eggs are carried by the ants into the deepest parts of the ant nests. At the return of the favorable season the eggs are brought forth again to places suitable for hatching. In this case the aphids, which are parasitic upon the corn roots, are themselves in slavery (*helotism*) to the ants, and this interrelation obviously reaches a high degree of development. When seed corn is treated with oil of lemon, the aphids are said to be repelled, for a time at least, from the young plants. Frequent cultivation disturbs the ant burrows, and birds that prey upon ants, as flickers and woodpeckers, also tend to reduce the damage done by the aphids.

309. Resistance to disease. Every kind of economic plant seems to have one or more plant or animal diseases. Each presents special problems, many of which are yet unsolved.

In some cases where solutions have not been forthcoming, attention is being centered upon securing resistant varieties of plants rather than upon preventing the disease. In open nature many plants thrive and are not affected by diseases which affect other plants of the same kind; that is, some plants are resistant and some are susceptible. Other plants may have certain diseases but are not killed by them, as in the case of the lilac and the disease known as lilac mildew. A good illustration of the value of the study of disease resistance is presented in connection with grape plants and an insect (phylloxera) which is parasitic upon the roots of the grape.

The grapes cultivated in Europe are descended from a European wild species; the principal varieties cultivated in the middle and eastern United States are descended from American wild species. Since the French grapes produced a quality of wine that differed from that made from the grapes of the United States, European grapes were brought to this country. Their roots were soon attacked and the plants well-nigh destroyed by the phylloxera. It was found, however, that the roots of the American grapes were able to withstand attacks from phylloxera and were not seriously affected by it. It was also found that when European grapes were brought to this country and grafted upon American stock, the quality of the European fruit might be secured without the accompanying dangers from the insect. But when grape growers transplanted American grapes into Europe, the phylloxera was also transferred, and soon the native grapes of Europe were attacked and serious damage was done in the vineyards of France. It was found that by treating the soil with carbon disulphide the phylloxera were killed, but this method usually proved too expensive for growers of grapes. Many French grape growers adopted the practice of planting American plants and then grafting their own grapes upon this introduced stock. The grape industry of France has been greatly increased by thus growing French varieties upon the stronger and more resistant American stock.

PROBLEMS

1. What is it that often causes suddenly submerged agricultural plants to become yellow and die?

2. What causes the bubbles that arise from the soil when a heavy shower is falling? What causes them to rise?

3. What are the worst plant diseases of your community? What has your state done to prevent these diseases? Do people in your community follow the directions of your agricultural experiment station relative to plant diseases?

4. What is the source of the dust that is deposited on window sills during windy weather?

5. Are soils blown away during windy weather?

6. Why are the branches of young trees pruned so heavily when the trees are transplanted? Why are they pruned as a means of fruit production?

7. Why do agriculturists ordinarily use low or level lands chiefly for cultivation and uplands chiefly for pasturage?

8. What effect upon the soil is supposed to be produced by rotation of crops? Is rotation advisable for the garden?

CHAPTER XX

WEEDS

310. What is a weed? The term *weed* is not a botanical one but is a common word for the conspicuous troublesome or injurious plants. It is not customary to apply the name *weed* to lower forms of plant life, such as bacteria and fungi, even though they may be extremely harmful to field and garden crops, orchards, or forests. Most weeds are flowering plants, but horsetails and a few ferns (as the sensitive fern, fig. 216) are sometimes troublesome enough to be classed in the list.

The same plant may be counted a weed in one place and not in another. The sensitive plant, not uncommon as a curiosity in our greenhouses, is a troublesome weed over immense areas in the tropics. Wild carrots, of the same species as the cultivated ones, are a nuisance in New England mowing lands and are rapidly extending westward; field garlic, melilot, horseradish, tansy, oxeye daisy, and orange hawkweed, or "paintbrush," were all introduced as valued garden plants, afterwards becoming noxious weeds.

311. Why weeds succeed. The characteristics which enable weeds to flourish where farm and garden crops need care to enable them to grow are too numerous to be stated and explained at length in a very elementary book. Some of the important characteristics which distinguish most weeds are:

1. Great reproductive power.

2. Capacity for rapid growth, which enables them to shade and destroy other plants.

3. Ability to resist drought, shading, frost, and plant diseases.

Any very prevalent and troublesome weed will usually be found to possess a considerable number of the qualities just stated. A good example of this is found in the common sorrel (fig. 241). It is rapidly propagated by its creeping roots, which may form a network throughout a piece of ground nine feet in diameter. As these roots form buds at short intervals, a single plant, when let alone, will soon become the center of a colony. Sorrel also seeds abundantly, and its seeds occur mixed with commercial grass seed and clover seed. It is little affected by drought or frost and flourishes in poor, thin soils, so that neglected pastures often become overrun with it. This sorrel, then, is a good example of the kind of weed that finds its way where the conditions are not very favorable to the growth of more robust plants, and that makes considerable headway beneath the shade of crops taller than itself.

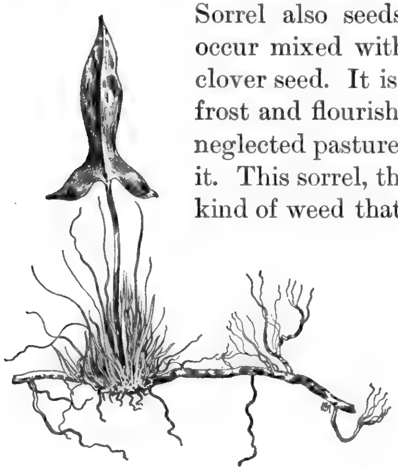

FIG. 241. Portion of a plant of the common sorrel

The leaf is drawn about one half natural size. The running roots of a large specimen would be at least sixty times as long as the piece here shown

An example of the opposite type of weed, that cannot reach anything like its full size except in deep, rich ground, is the common ragweed (fig. 242). Under favorable conditions this grows so large as to crowd out other plants. It cannot reproduce itself except by seed, but the seeds are abundant (often more than 20,000 in number); the seedlings soon become stout and branching, with a deep taproot which robs all neighboring plants of water and food materials. Other familiar weeds of rich ground with the robust habit of the ragweed are pigweeds (*Chenopodium*) of several species, two or three species of rough pigweeds (*Amaranthus*), several kinds of dock, the Indian mallow or butter print (*Abutilon*), and sunflowers.

312. How weeds injure the farm and garden.[1] Although some weeds are of use as food for man or the lower animals, and a few have medicinal properties, their presence in the farm or garden is on the whole most harmful in the following ways:

1. Weeds take moisture needed by useful plants.

2. Weeds rob the soil of valuable salts, such as nitrates and potash compounds, and it is probable that they may add secretions that are injurious.

3. Weeds shade other plants, thus weakening them by hindering photosynthesis.

4. A few parasitic weeds, like the clover dodder (fig. 243), rob their hosts of plant food.

5. Some weeds harbor parasitic fungi or insects (such as the potato beetle) which are injurious to useful plants.

FIG. 242. The common ragweed (*Ambrosia artemisiaefolia*)

The group of flower clusters at the left and the leaf at the right are considerably reduced, and the central plant is much reduced. The slender stem is characteristic of individuals grown in the shade; plants grown in the sunlight are much shorter and very robust

[1] See also Bergen and Caldwell, Practical Botany. Ginn and Company, Boston.

6. Poisonous or intoxicating plants injure horses, cattle, and sheep.

7. Some spiny plants (such as the smaller cacti) and burs (like the sand bur) may lame the feet of domestic animals. Thorny shrubs are very troublesome to woolgrowers, as they pull out much wool, and the burs greatly injure the quality of the fleece.

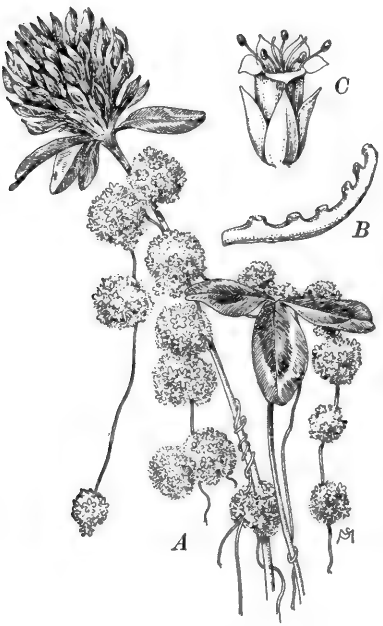

FIG. 243. Clover dodder, parasitic on red clover

A, habit sketch of part of the parasite and the host; *B*, portion of stem of the dodder, showing protuberances from which haustoria pass into the stem of the host; *C*, a single flower of the dodder. *B* and *C* considerably magnified. Modified after "Flora Danica"

8. Certain weeds, when eaten by cows, render milk unpalatable or ill-scented.

9. Weed seeds injure the quality and affect the price of clover and other seeds that are raised for sale.

313. Amount of damage caused by weeds. It is impossible to put into exact figures the amount of damage annually done by weeds in the United States, but it probably aggregates over $200,000,000 a year.[1]

The expense caused by weeds is largely for extra labor of men and animals,

[1] The estimate here given is by Professor Frederick V. Coville, and is based on the assumption that the loss may amount to 5 per cent of the total value of the principal crops of the United States. The estimated value of the crop of corn, wheat, oats, barley, rye, buckwheat, flaxseed, rice, potatoes, hay, tobacco, and cotton for the year 1912 was $4,693,000,000.

Another estimate by an expert in the Department of Agriculture places the loss at about $300,000,000.

but much also is expended for extra wear and tear of farm implements and machinery and for the purchase of implements which are only needed for contending with weeds. It is worth while to notice that the labor expended in destroying weeds is not all dead loss, as the loosening and turning over of the soil is often of much use to the growing crops.

Aside from the damage which they inflict on crops, weeds cause much inconvenience and loss, as they infest roadsides and railroad rights of way, and choke up streams, canals, and irrigation ditches.

FIG. 244. The buffalo bur (*Solanum rostratum*)

This is a troublesome weed in grainfields. It is traveling eastward from the Great Plains near the Rocky Mountains. It is often distributed by being blown about as a tumbleweed. One sixth natural size

314. Where our weeds originated.[1] Among the most troublesome weeds in the long-settled portions of the country about half are of European origin and several came from tropical America and from India. Only about 40 per cent are native American species.[2]

Naturally most of the European weeds introduced into this country have traveled rather slowly inland from the Atlantic coast. Some species, like the common groundsel (fig. 19), chicory, butter and eggs, wild carrot, and wild parsnip, are still much more common in the maritime provinces of Canada and in New England than

[1] See the article "Pertinacity and Predominance of Weeds," in the Scientific Papers of Asa Gray, selected by C. S. Sargent, Vol. II, Houghton Mifflin Company, Boston; also "Farm Weeds of Canada," Second Edition, Government Printing Bureau, Ottawa, Canada.

[2] *Farmers' Bulletin 28*, U.S. Dept. Agr.

farther westward. A few weeds, like the buffalo bur (fig. 244), have made their way eastward from the Great Plains.

315. How to avoid and destroy weeds. It is often easier to keep weeds out of cultivated ground than to destroy them after they get a foothold there. The principal means of avoiding weeds are to plant as few weed seeds as possible and to allow few to be planted by natural agencies. This means that the seeds used for the farm and garden shall be as free as possible from weed seeds, that all manure used shall contain as few weed seeds as possible, and that all spots which might serve as breeding places for weeds must be carefully watched and prevented from seeding the adjacent ground. Neglected fence rows and other bits of uncultivated land may grow enough

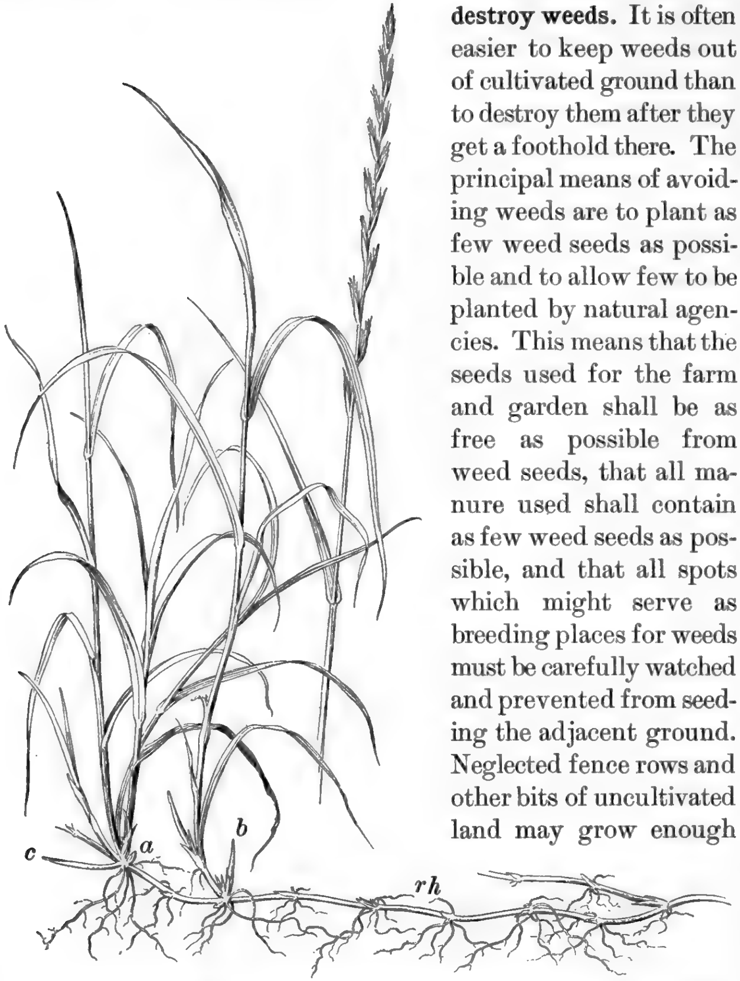

FIG. 245. Couch grass, one of the worst weeds of the northeastern states

It is rapidly propagated by its long rootstocks (*rh*). Note the manner in which young shoots (*a*, *b*, *c*) are shown arising from the nodes of the rootstock

readily transported seeds, such as goldenrod, thistles, prickly lettuce, and milkweeds, to seed all adjoining parts of the farm.

Many useful plants and still more harmful ones spread by vegetative means so as to overrun neighboring ground. In this way a blackberry patch may spread by the root so as to become a nuisance, and black raspberry bushes will travel by means of their long rooting branches (fig. 72) so as to cover much ground. Couch grass, or quack grass (fig. 245), growing beside a cultivated field or garden will soon spread into the cultivated soil by means of its vigorous rootstocks.

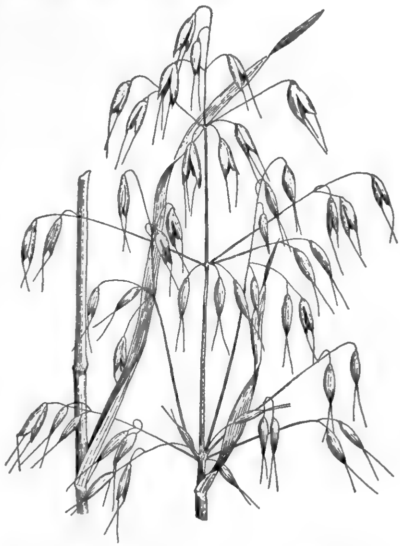

FIG. 246. Wild oats, a grass belonging to the same genus as the cultivated oat

It is an extremely troublesome weed, especially in fields of the small grains. After "Farm Weeds of Canada"

Methods of destroying weeds cannot be treated in detail in a textbook on botany, though a few words may be given to the subject. Weeds which have gone to seed should not be plowed or spaded under, but should be burned when dry. It will be found well worth while to rake away from fences and burn all accumulations of tumbleweeds. Wild mustard, which is a very troublesome weed in fields of the small grains, is readily killed by spraying with a solution of copper sulphate or iron sulphate. Weedy lawns are sometimes improved by very careful salting, which does not injure the grass. Gravel walks may be cleared of weeds by watering them with a highly poisonous solution of sodium arsenate or of crude carbolic acid. Rotation of crops (that is, following the crop of one year by a

very different one the next year) often rids the ground of the most troublesome weeds. Such weeds as wild oats (fig. 246), foxtail grass, and wild mustard are very injurious in fields of the small grains; they do little damage in cornfields, and changing the crop from wheat to corn for a year or two helps to reduce these weeds. Many of the worst weeds in grasslands and pastures, such as the common sorrel (fig. 241), wild carrot, wild parsnip, buttercup, moth mullein, common mullein, orange hawkweed, oxeye daisy, and yellow daisy, do little harm in cornfields. At times these weeds and many others become very harmful in grasslands. If such grasslands are plowed, and a cultivated crop, as corn or potatoes, is grown for one or two years, these weeds may be effectively removed.

PROBLEMS

1. Name five of the worst weeds of cornfields in your region; five of fields of small grains; five of grasslands. Which, if any, of these weeds are not natives of this country?

2. What is the most troublesome weed in the gardens that you know? Why? What is the best method of destroying it?

3. Give an example of a weed that thrives best in wet soil; of one that will grow in very dry soil; of one that is little injured by trampling; of one that is so offensive to grazing animals that it is never eaten by them; of one that is not killed by being uprooted and left exposed.

4. Describe the way in which the seeds or fruits of ten common weeds are dispersed.

5. Which of these kinds of seeds are very likely to be bought mixed with many weed seeds: corn, ordinary grasses, wheat, clover, beets? Explain. How is the difficulty to be avoided? remedied?

6. Give an example of a weed that is troublesome in spite of having no very efficient means of seed dispersal.

7. Try to give some reasons for the fact that a majority of our worst weeds are of foreign origin — largely European.

8. Explain why rotation of crops, such as plowing a mowing field and seeding it to corn, tends to destroy weeds.

9. Give instances of useful plants of the farm or garden that you have found growing like weeds among other crops.

10. In the following table the names in each line at the left of the vertical line are those of cultivated plants; the names at the right, those of wild plants of the same family or even more closely related. Explain in each case, as well as you can, why the cultivated plant would be unable to maintain itself in competition with its wild relatives if they were growing side by side.

wheat, corn	grasses occurring as weeds
beets, spinach	pigweeds
peonies	buttercups
garden strawberries	cinquefoils
pansies	blue dooryard violets[1]
scarlet salvia	catnip
potato, tomato	Jimson weed, horse nettle, ground cherry
lettuce	dandelion

11. How should we treat a lawn infested with dandelions? with chickweed? with undesirable grasses?

[1] *Viola papilionacea, V. sororia.*

APPENDIX

PHOTOSYNTHESIS

The chemistry of photosynthesis is not completely known, but some of the simpler aspects of it may prove valuable to the student. The chemist's formula for water is H_2O, in which H stands for hydrogen and O for oxygen, and the figure 2 indicates that two parts of hydrogen are united with one part of oxygen. Similarly, CO_2 indicates that one part of carbon is united with two parts of oxygen to form carbon dioxide. When these compounds are broken up, there is, for a very brief time at least, free C, H, and O. If one unit of each compound (H_2O and CO_2) is thus broken up, there will be two H, one O, one C, and two O — or in all three O. After photosynthesis has been going on for some time, starch is usually formed. Starch consists of $(C_6H_{10}O_5)_n$. This means that six parts of carbon, ten parts of hydrogen, and five parts of oxygen unite to form starch, and the *n* means that the unit $C_6H_{10}O_5$ does not appear singly, but that an unknown number of them are united. Disregarding the fact that several of the starch units are held together, and considering the single unit $C_6H_{10}O_5$, we may be able to see what happens in the work of photosynthesis. To secure the amount of carbon necessary to form starch, six times the unit CO_2 must be taken, since six units of carbon are to be used. To secure the needed amount of hydrogen, five times the unit H_2O must be used, since there must be ten units of hydrogen, and two are secured with each unit of water. We have therefore 6 (CO_2) and 5 (H_2O). When the energy of the sun has broken these things into their constituent parts, there are 6 (C), 12 (O), 10 (H), and 5 (O) — or 17 (O) in all. But starch consists of

$C_6H_{10}O_5$, and in making this unit of starch there has been used all of the carbon, all of the hydrogen, and five units of the oxygen, thus leaving twelve units of oxygen to be set free or to be used by the plant in some other way. Some of this free oxygen passes into the air, though some of it is used by the plant in a later process.

The compounds thus constructed, such as starch and sugar, are called carbohydrates, the name indicating that they are compounds of carbon and water.

GLOSSARY

Abortive. Imperfectly developed, as in abortive stamens.

Absorption. Act of taking in substances through the tissues.

Accessory fruits. Fruits reënforced by ripening of stem or other structures together with ordinary fruits, as in strawberry, apple, pear, quince.

Adventitious buds. Buds that spring from various parts of the root or stem, not from nodes.

Aërial roots. Roots that develop in the air.

Akene. A small, dry, one-seeded fruit in which the ovary wall adheres to the seed, as in sunflower, dandelion, and grains of common cereals.

Albuminous seeds. Seeds that, when ripe, contain endosperm.

Aleurone. Grains of definite structure containing protein food; aleurone grains are often found in a single layer of regular cells just within the seed coat.

Alternation of generations. Alternating of a sexual and a sexless generation in the life cycle of a plant.

Ament. The flower cluster of trees and shrubs, such as oak, willow, etc.

Anabolism. Building-up processes; making and assimilating food materials.

Anaërobes. Plants that cannot carry on their life processes in presence of ordinary air.

Anatropous (turned up). Applied to ovules or seeds that grow in an inverted position.

Andrœcium (male household). Stamens of a flower collectively; this name was given when stamens were thought to be male sex organs.

Anemophilous flowers (wind-loving flowers). Those whose fertilization is effected by means of the wind.

Angiosperms (inclosed seeds). One of the two groups of spermatophytes (seed plants).

Annulus (a ring). The elastic ring of cells around the sporangium in ferns.

Anther. The pollen-bearing part of the stamen.

Antheridiophores. Stalks upon which antheridia are borne.

Antheridium; pl. **antheridia**. The male sex organ in the lower groups of plants.

Antherozoid. See *Sperm.*

Antipodal (against the foot). Applied to a group of cells at the end of the embryo sac farthest from the micropyle.

Apetalous. Without petals.

Apical. At the apex or tip.

Apocarpous (without carpels). Applied to flowers in which the carpels are entirely free from one another.

Appressed. Lying flat throughout its length, as appressed bracts.

Association. An ecological unit group smaller than a plant formation, of which the latter is sometimes made up.

Awl-shaped. Narrow, tapering to a point, as awl-shaped leaves.

Awned. Having bristle-like appendages, as in heads of many kinds of wheat.

Basidium (club); pl. **basidia.** The specialized club-shaped cells on which the spores of some fungi are borne.

Bast. The phloëm portion of a fibrovascular bundle. It may be fibrous (hard bast), or composed of sieve tubes (soft bast).

Bilabiate (two-lipped). Applied to the form of corolla in certain dicotyledonous plants.

Bract (a thin plate). The small, scale-like, modified leaves which sometimes are found at the base of the flower cluster.

Calyptra (a cover). In mosses, the hood that covers the tip of the capsule.

Calyx (a cup). All the sepals, which together form the outer envelope of a flower.

Cambium. The meristem cells of a fibrovascular bundle lying between the phloëm and xylem, and having the power of division, so as to produce new phloëm and xylem.

Capitate (relating to head). (1) Rounded, as the head of the stigma of the primrose; or (2) growing in heads.

Capsule (a small box). A dry, dehiscent seed vessel (formed of more than one carpel).

Carpel (fruit). The megasporophyll; hence either a simple pistil or one of the parts of a compound pistil.

Carpellary. Relating to a carpel.

Catkins. See *Ament.*

Caulicle (a small stem). The initial stem in an embryo.

Cell. The morphological or anatomical unit of plant and animal structure.

Cellulose (pertaining to a cell). The primary substance of the cell wall.

Central cylinder. The stele, or portion of the root or stem which is inclosed by the primary cortex.

Chaff. Small dry scales usually found in connection with the seeds of plants, as in grasses and *Compositæ*.

Chalaza. The base of an ovule where integuments and nucellus are one common tissue.

Chlorophyll (green leaf). The green coloring matter of plants.

Chloroplast. One of the special bodies that contain chlorophyll.

Choripetalous (separate petals). With the petals separate, not united.

Chromatophore (color-bearing). A general term for all bodies in plants containing coloring matter.

Cilium (eyelash); pl. **cilia.** Marginal hairs; motile protoplasmic filaments, as those of sperms.

Cleistogamous. With close fertilization, occurring in flowers before they open.

Closed bundle. A fibrovascular bundle containing no cambium; growth is closed.

Cœnocyte. A number of nucleated masses of cytoplasm (cells) inclosed by a common wall.

Collateral (sides together). Side by side, as in a fibrovascular bundle in which the xylem and phloëm are side by side in a radial direction.

Columella (a small column). The persistent axis of certain spore cases, as in mosses.

Concentric (center together). Technically used of a fibrovascular bundle whose tissues are arranged so as to surround one another.

Conidiophore (conidium-bearer). Stalk upon which conidia are borne.

Conidium; pl. **conidia.** The asexual spore of some fungi, as in potato blight and grape mildew.

Conjugation (joined together). The sexual union of similar gametes.

Connate. Applied to leaves that appear united or grown together at their bases.

Connective. The portion of the stamen connecting the parts of the anther.

Cordate. Heart-shaped.

Corm. The fleshy stem or base of a stem; a bulb-like structure, as on the underground part of jack-in-the-pulpit.

Corolla (a small crown). The inner envelope of a flower within the calyx, composed of petals.

Cortex. Rind or bark.

Cortical. Relating to cortex.

Cotyledon. A primary embryo leaf borne by the hypocotyl (caulicle) of the embryo plant.

Cryptogams (hidden marriage). A term used to include thallophytes, bryophytes, and pteridophytes.

Cupule (a little cup). The gemma cup of liverworts.

Cuticle (skin). The outermost layer of epidermis, differing chemically from the remainder of the cell wall.

Cutinization. The transformation of the outer layer of the epidermis into *cutin*, a substance which is nearly waterproof and not easily penetrated by gases.

Cyclic. An arrangement of leaves or floral organs in such a way that two or more appear upon the axis at the same level, thus forming a cycle or whorl.

Cytoplasm. The jelly-like living material of the cell.

Deciduous. Applied to plants which lose their leaves at regular intervals.

Dehiscence (gaping). The opening of an organ to discharge its contents, as in case of anthers, sporangia, and capsules.

Dermatogen (skin-producer). The layer of young epidermis in growing points.

Dichogamous. With stamens and pistils not maturing together, as in many plantains.

Dichotomous (cutting in two). Forked regularly in pairs.

Dicotyledonous (cotyledons double). Having two cotyledons or seed leaves.

Dimorphism (two structures). Having two different forms. Long-styled and short-styled flowers of the same species are dimorphous.

Diœcious (two households). Having the two kinds of reproductive organs borne by separate individuals.

Dorsiventral. Having the two surfaces differentiated so that one is upper and one lower.

Drupe. A stone fruit with a fleshy outer and a hard inner layer of the pericarp, as in the walnut, peach, plum, etc.

Ecology. The study of the relations between the plant and its environment, including the other living beings with which it has to do.

Egg or **oösphere.** The female gamete.

Egg apparatus. A group of three cells, consisting of the egg and two synergids, one at each side. Found in angiosperms.

Embryo. The young plantlet within the seed.

Embryo sac. The cavity within which the embryo develops.

Endodermis (within the skin). The layer of cells inclosing the fibro-vascular bundle; the bundle sheath.

Endogenous (produced within). Originating from internal tissues.

Endosperm (within the seed). A tissue containing reserve materials developed within the embryo sac.

Endosperm nucleus. The nucleus of the angiosperm embryo sac from which the endosperm of the embryo sac develops.

Enzyme. One of the plant secretions which digest substances external to the plant, as in carnivorous plants, or reserve materials, as in seeds.

Epiphyte. A plant which grows upon other plants.

Fertilization. The act of uniting an egg and a sperm.

Fibrovascular bundles (fiber vessels). The strands that make up the framework of higher plants.

Filament (a thread). The stalk of the stamen that supports the anther; also the individual threads of algæ or fungi.

Filiform. Thread-like.

Fission (splitting). Cell division resulting in division into halves.

Fleshy. Thick, succulent.

Flowering glume. In grasses, the bract that subtends each flower, sometimes called lower palet.

Formation. An ecological group. It signifies a well-defined assemblage of plants characteristic of some kind of station.

Frond (a leaf). A name given to the leaf of ferns.

Fruit. The ripened ovary and its contents.

Funiculus (a slender rope). The stalk of an ovule or seed.

Gametangium (gamete vessel). The specialized organ for production of gametes.

Gamete. A reproductive cell which ordinarily becomes functional only upon union with another. As a result of this union a sexual spore is formed.

Gametophyte (gamete plant). The sexual stage of an alternating plant.

Gemma (a bud); pl. **gemmæ.** In bryophytes, many-celled buds specialized for vegetative propagation.

Generative cell. The cell within the male gametophyte of spermatophytes (usually within the microspore wall) which divides to form the two male cells.

Geotropism (turning toward the earth). The tendency of organs or portions of organs to go downward.

Glaucous (pale green, gray). Whitened with a bloom, like that on a cabbage leaf.

Glume (a husk). A chaff-like bract belonging to the inflorescence of grasses; the outer glumes subtend the spikelet; the flowering glume is the bract of the flower.

Gluten (glue). A term used for the glue-like products of plants, especially of seeds.

Grain. A seed-like fruit, like those of grasses, with pericarp grown fast to the seed; also any small, rounded body, as of starch.

Growing point. The group of meristem cells at the growing tip of an organ, from which the various tissues arise.

Guard cells. The cells (usually two) which open and close a stoma.

Gymnosperms (naked seeds). One of the two groups of spermatophytes (seed plants).

Gynæcium (female household). The pistil, or collectively the pistils, of a flower.

Halophyte. A plant which can thrive in saline soil, as that of "alkali" lands or salt marshes.

Haustorium (drinking organs); pl. **haustoria.** The absorbing organs of some parasites.

Heliotropism (turning to light). Tendency of plants to turn toward the sun.

Heterogamy (unlike gametes). The condition of plants whose pairing gametes are dissimilar.

Heterogamous. Pertaining to heterogamy.

Heterospory (unlike spores). The condition in plants which produce two kinds of asexual spores.

Heterosporous. Pertaining to heterospory.

Homospory (similar spores). The condition in plants which produce but one kind of asexual spore.

Homosporous. Pertaining to homospory.

Host. The plant upon or within which parasitic plants or animals develop, and from which they obtain nourishment.

Hybrid. A plant which is the offspring of an egg of one species fertilized by the pollen of another species. The term is also used for crosses between two varieties of plants.

Hydrophyte (water plant). A plant thriving only in water or marshes.

Hygroscopic (moisture seeking). Having an avidity for water.

Hymenium (a membrane). In fungi, a surface layer of interwoven filaments from which the spore-bearing filaments arise.

Hypha (a web); pl. **hyphæ.** The slender vegetative filaments of fungi which may or may not be woven into a mat (*mycelium*) or a definitely organized plant.

Hypocotyl. The short stem of an embryo seed plant.

Hypodermis (under the skin). The tissues which lie immediately beneath the epidermis and which serve to strengthen it.

Hypogynous (being under the ovary). Applied to those flowers whose stamens and floral envelopes are at the base of the ovary.

Indehiscent. Not dehiscent, or not splitting regularly.

Indusium (covering); pl. **indusia.** In ferns, a cellular outgrowth of the leaf covering the clusters of sporangia (*sori*).

Inflorescence (flowering). The arrangement of flowers; or the flowering portion of a plant.

Integument (covering). The covering of the ovule.

Intercellular. Between or among the cells.

Internode. The part of a stem between two nodes or joints.

Intine (on the inside). The inner coat of a pollen grain.

Involucre (rolled within). The leaf-like or bract-like sheath that incloses a cluster of flowers.

Irritability. The capacity which protoplasm possesses of responding to stimuli, such as light, heat, gravity, and contact with chemical reagents.

Isogamous (equal gametes). Applied to those plants whose pairing gametes are similar.

Lamina (a layer). The blade or expanded part of a leaf.

Leaf trace. The fibrovascular bundles from the leaf which blend within the stem with its fibrovascular cylinder.

Lenticel. A round, oval, or lens-shaped opening on the exterior surface of the bark.

Leucoplast (white molded). A minute colorless body within a cell. When exposed to light, leucoplasts may develop into chloroplasts.

Liana. A climbing plant.

Ligule (a small tongue). In grasses a thin appendage at the junction of leaf blade and sheath.

Medullary. Relating to the pith; medullary rays are the pith rays which radiate to the bark between the fibrovascular bundles.

Megasporangium (large spore vessel). The sporangium that produces the megaspores.

Megaspore (great or large spore). The larger one of the two kinds of asexual spores produced by certain pteridophytes and all spermatophytes.

Megasporophyll (large spore leaf). The leaf upon which the megasporangium develops.

Meristem (dividing tissue). Tissues with the cells all nearly alike and still capable of subdividing.

Mesophyll (middle leaf). The green or soft tissue of the inner part of the leaf.

Mesophytes (middle plants). Normal land plants such as grow in an average soil and under a moderate climate.

Metabolism. Chemical transformations of matter carried on by plants in the production and utilization of their food supply, and disposition of waste products.

Micropyle (small gate). The opening left by the integuments of the ovule, and which leads to the nucellus.

Microsporangium (small spore vessel). The sporangium that produces the microspore.

Microspore (small spore). The smaller spore of the two kinds produced by certain pteridophytes and all spermatophytes.

Microsporophyll (small spore leaf). The leaf upon which the microsporangium is borne.

Midrib. The central or main rib of a leaf or thallus.

Monœcious (one household). Applied to those plants upon one of which both kinds of gametes are borne. Strictly speaking, the term applies only to the gametophyte stage of plants. A monœcious seed plant bears both staminate and pistillate flowers.

Monopodial (having one foot). Said of a stem consisting of a single and continuous axis (footstalk).

Mother cell. A cell that produces new cells (usually) by internal division.

Mutualism. A symbiotic relationship in which the organisms are mutually helpful.

Mycelium (fungous growth). The filamentous vegetative growth of fungi, composed of hyphæ.

Naked. Wanting some usual covering.

Nascent. Developing or growing.

Nastic movements. Movements produced by all-round stimuli, as heat. The opening and closing of the flowers of crocuses and tulips are thermonastic movements.

Nectary. The structure in which nectar is secreted.

Nerve. A simple vein or rib.

Node (a joint). That part of a stem which normally bears leaves.

Nucellus (a little kernel). The mass of the ovule within the integuments.

Nucleolus (diminutive of nucleus). The sharply defined rounded part often seen in the nucleus.

Nucleus (a kernel). The usually roundish mass found in the protoplasm of most active cells, and differing from the rest of the protoplasm in its greater density.

Oögonium; pl. **oögonia.** The female reproductive organ of thallophytes.

Oösphere (egg sphere). The egg cell; the mass of protoplasm prepared for fertilization.

Oöspore (egg spore). The egg cell after fertilization.

Open bundle. A fibrovascular bundle which contains cambium.

Operculum (a cover or lid); pl. **opercula.** In mosses the terminal lid of the capsule, just beneath the calyptra.

Osmosis. The interchange of liquids through a membrane.

Ovary (egg-keeper). That part of the carpel in which the ovules are formed.

Ovule (an egg). The body which becomes a seed after fertilization and maturation; formerly thought to be an egg.

Palet (chaff). In grasses, the inner bract of the flower.

Palisade cells. The elongated parenchyma cells of a leaf, which stand at right angles to its surface and are often confined to the upper part of the leaf.

Palmate (pertaining to the hand). Radiating like the fingers; said of the veins or divisions of some leaves.

Panicle (a tuft). A loose and irregularly branching flower cluster, as in many grasses.

Pappus (down). The modified calyx of the composites.

Paraphysis (accompanying organs); pl. **paraphyses.** Sterile bodies, usually hairs, which are found mingled with the reproductive organs of various lower plants.

Parasite. An organism that obtains its food from the living tissues or the secretions of other organisms.

Parenchyma. Ordinary or typical cellular tissue, i.e. of thin-walled cells nearly equal in all their dimensions.

Parthenogenesis. The formation, without fertilization, of a spore which is functionally the same as a sexual spore. In general it means that the female gamete becomes a spore directly, and may grow without fertilization.

Pedicel (a little foot). The stalk upon which a structure is borne.

Peduncle (a little foot). The flower stalk.

Pentacyclic (five cycles). Applied to flowers whose four kinds of floral organs are in five cycles.

Perianth (around the flower). The floral envelopes or leaves of a flower, taken collectively; and an analogous envelope of the sporogonium of certain liverworts.

Periblem (a cloak). A name given to that part of the meristem at the growing point of the plant axis, which lies just beneath the epidermis and develops into the cortex.

Pericambium (surrounding growing tissue). In roots, the external layer of the fibrovascular cylinder.

Pericarp (around the fruit). The wall of the ovary, developed into a part of the fruit.

Perigynous (around the ovary). Applied to those flowers whose stamens and perianth arise from around the wall of the ovary.

Peristome (around the mouth). In mosses, usually bristle-like or tooth-like structures surrounding the orifice of the capsule.

Petal (a leaf). A corolla leaf.

Petiole (a little foot). The stalk of a leaf.

Phanerogamia (evident marriage). A primary division (the highest) of plants, named, from their mode of reproduction, the seed-producing plants. Phanerogam is the English equivalent.

Phloëm (the inner bark). The bark or bast portion of a fibrovascular bundle.

Photosynthesis (light construction). The name applied to the process by which chloroplasts under the influence of sunlight manufacture such carbohydrates as sugar and starch from water and carbon dioxide.

Phycocyanin (seaweed blue). A bluish coloring matter found within certain algæ.

Phyllotaxy. Leaf arrangement.

Pinna (a feather); pl. **pinnæ.** One of the primary divisions of a pinnate leaf, as in ferns.

Pinnate. Having the veins or the divisions of the leaf arranged in rows on each side of the midrib, as in black locust (*Robinia*).

Pinnule (a little feather). One of the divisions of a pinna.

Pistil (a pestle). A simple or compound carpel in spermatophytes.

Placenta; pl. **placentæ.** That portion of the ovary which bears the ovules.

Plerome (that which fills). A name given to that part of the meristem, near the growing points of the plant axis, which forms a central shaft or cylinder and develops into the axial tissues.

Plumule (a little feather). The terminal bud of the embryo above the cotyledons.

Pod. A dry, several-seeded, dehiscent fruit.

Pollen. The spores developed in the anther.

Pollen tube. The structure that develops from the wall of the microspore of spermatophytes and carries male cells to the egg.

Pollination. The transfer of pollen to the stigma.

Polypetalous (many petals). Applied to flowers that have their petals free from one another.

Prosenchyma. Tissue composed of elongated cells, with tapering ends which overlap.

Prothallium (a forerunning shoot); pl. **prothallia.** The small, usually short-lived plant which develops from the spore and bears the sex organs.

Protonema (that which is first sent out); pl. **protonemata.** In mosses, the filamentous growth which is produced by the spores, and from which the leafy moss plant is developed.

Protoplasm (that which is first formed). The living matter of cells.

Pubescent. Downy, with fine hairs.

Pyrenoid (kernel formed). Minute colorless bodies embedded in the chlorophyll structures of some lower plants.

N.B.

Receptacle. That portion of an axis or pedicel (usually broadened) which forms a common support for a cluster of organs, either sex organs or sporophylls.

Respiration. The series of processes by which plants obtain energy through breaking down of protoplasm or food. Usually oxygen is used and carbon dioxide is formed as a result of the process.

Reticulated (net-like). Having a net-like appearance.

Rhizoid. Root-like; a name applied to the root-like hairs found in bryophytes and pteridophytes.

Rhizome. See *Rootstock.*

Rootstock. A horizontal, more or less thickened, root-like stem, either on the ground or underground.

Saprophyte. An organism that obtains its food from dead or decaying organisms.

Scalariform (ladder form). A name applied to ducts with piths horizontally elongated, and so placed that the intervening thickening ridges appear like the rounds of a ladder.

Scale (a flight of steps). Any thin scarious body, as a degenerated leaf, or flat hair.

Sclerenchyma. A tissue composed of cells that are thick-walled, often extremely so.

Seed. The matured ovule.

Sepal. A calyx leaf.

Seta; pl. **setæ.** A bristle, or bristle-shaped body; in mosses, the stalk of the capsule.

Sexual spore. One formed by the union of cells.

Sheath. A thin enveloping part, as of a filament, leaf, or resin duct.

Sieve cells. Cells belonging to the phloëm, and characterized by the presence of perforated plates in the wall.

Sorus (a heap); pl. **sori.** In ferns, the groups of sporangia, constituting the so-called "fruit dots"; in parasitic fungi, well-defined groups of spores, breaking through the epidermis of the host.

Sperm, or **Spermatozoid** (animal-like sperm). The male gamete.

Spermatophytes (seed plants). The highest great group of plants, of which a characteristic structure is the seed.

Spike. A flower cluster, having its flowers sessile on an elongated axis.

Spikelet (diminutive of spike). A secondary spike; in grasses, the ultimate flower cluster, consisting of one or more flowers subtended by a common pair of glumes.

Sporangium (spore vessel); pl. **sporangia.** The spore-producing structure.

Spore (seed). Originally used as the analogue of seed in flowerless plants; now applied to any one-celled or few-celled body which is separated from the parent for the purpose of reproduction, whether sexually or asexually produced; the different methods of its production are indicated by suitable prefixes.

Sporogonium (spore offspring); pl. **sporogonia.** The whole structure of the spore-bearing stage of bryophytes.

Sporophyll. A leaf that bears sporangia.

Sporophyte (spore plant). The asexual or spore-producing stage of an alternating plant.

Stamen. The microsporophyll in spermatophytes.

Stigma. That portion of the surface of a pistil (without epidermis) which receives the pollen.

Stigmatic. Relating to the stigma, or stigma-like.

Stoma (a mouth); pl. **stomata.** Epidermal structures which serve for facilitating gaseous interchanges with the external air, and for transpiration of moisture. They are often incorrectly called "breathing pores."

Strobilus. A cone-like cluster of sporophylls.

Style. The usually attenuated portion of the pistil which bears the stigma.

Succulent. Thick and fleshy.

Suspensor. A chain of cells which develops early from the oöspore, and serves to push the embryo cell deep within the embryo sac.

Symbiont. One of the organisms that has entered into a symbiotic relationship.

Symbiosis (living together). Applied to a condition in which two or more organisms are living in an intimate relationship.

Sympetalous. Having the petals apparently all united, as if grown together by their edges.

Syncarpous (carpels united). Applied to those conditions in which the carpels have united into a compound pistil.

Synergids (helpers). The two nucleated bodies which accompany the oösphere in the embryo sac, and together with it form the egg apparatus.

Testa (a shell). The outer seed coat.

Tetracyclic (four cycles). Applied to those flowers in which there are four cycles of floral organs.

Tetradynamous (four strong). Said of a stamen cluster in which there are four long and two shorter stamens.

Thalloid. Thallus-like.

Thallus (a young shoot). The body of lower plants, which exhibits no differentiation of stem, leaf, and root.

Tissue. A texture built up of mutually dependent cells of similar origin and character, as the cambium layer.

Tracheid. A long, slender cell, with closed ends and its walls thickened after the cell has attained its full size, as in the pitted cells of coniferous wood.

Transpiration. The loss of water derived from the interior of the plant body in the form of vapor. The term is not generally used with reference to plants of low organization.

Trichome (a hair). A general name for a slender outgrowth from the epidermis, usually arising from a single cell.

Turgidity. The normal swollen condition of active cells which results from the distension brought about by absorption of water.

Unisexual. Having only male or only female reproductive organs.

Vein. One of the fibrovascular bundles of leaves or of any flat organ of plants.

Venation. The mode of vein distribution.

Xerophyte. A plant capable of thriving under conditions of strongest transpiration and with scanty water supply.

Xylem (wood). The wood (inner) portion of the fibrovascular bundle.

Zoöspore (animal spore). A motile asexual spore.

Zygomorphic. Said of a flower which can be bisected by only one plane into similar halves, bilaterally symmetrical.

Zygospore (yoke spore). The spore formed by conjugation of similar gametes.

INDEX

(References to illustrations are indicated by asterisks accompanying page numbers. When an asterisk precedes the citation of a group of pages, it means that several illustrations are included)

KEY AND FLORA

NORTHERN AND CENTRAL STATES

BY

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PREFACE

This flora is a considerably enlarged revision of the one prepared by the author in 1901. It does not profess to describe all the conspicuous seed plants of any locality, but rather to comprise a large number of the most available spring-blooming species over an extensive region. More than a hundred species have been added to the list included in the older edition, mainly of plants which range westward to the moderately high plains. The little book may therefore afford a good deal of practice in the determination of species to secondary-school pupils in states even as far west as the Dakotas, Nebraska, Kansas, and Oklahoma. It extends south about to the southern boundary, of Kansas on the west and to that of Virginia on the east.

In the matter of nomenclature it seems best for those who do not wish to be hopelessly sectional to follow the rulings of the Vienna Congress. The author deems himself fortunate to have been able in this connection to avail himself of the decisions of the staff of the Gray Herbarium, as embodied in the seventh edition of Gray's *Manual of Botany*, and to get advice from the same source in regard to names of cultivated plants not described in the Manual. His most sincere thanks are hereby tendered for this invaluable assistance.

At the risk of sometimes seeming pedantic the writer has adopted the practice of discarding, for the most part, such unscientific expressions as "stemless plants," "radical leaves," "calyx adnate to the ovary," and several others. It is certain that if the plant descriptions which contain such terms were now being framed for the first time on the basis of present-day morphology, these terms would not be used.

Most of the plants here described bloom before the end of the school year, and it is believed that all of those which occur toward the southern limits of the territory covered will be found to flower there considerably before the end of June. It

may be found worth while, in the case of some *Umbelliferæ*, *Boraginaceæ*, and *Compositæ*, to collect fruit during the summer before it is to be used, preserve it either dry or in preservative fluid, as may seem best, and use it with freshly collected flowers in the determination of species.

No systematic work with seed plants can be of much use unless the teacher takes constant pains to bring out the idea of actual relationship by descent among the forms studied, and to show, in the simpler cases available, some of the steps of evolution. The beginner must not be allowed to suppose that the flora which he is using contains more than a small fraction of the total number of plants even in the families treated. He must be made to realize that the *Rubiaceæ*, for instance, of which he has fourteen species described, really number as many as 4500 species, and the *Compositæ*, instead of mustering a few dozen strong, number in all at least 12,000 species. For such comparisons Engler's *Syllabus der Pflanzenfamilien* will be found to contain the most recent and compact summary.

A somewhat complete (phanerogamic) flora of the student's region should be constantly in use. For this purpose the author prefers to all others the seventh edition of Gray's *Manual of Botany*. For the convenience of those who may find it necessary to use Britton's *Manual of the Flora of the Northern States and Canada*, the generic name used by Britton will generally be found in parenthesis after the name sanctioned by the Vienna code. In cases where Britton's genus covers only part of the genus as given in this book, a statement to that effect is made, as on p. 186, — B. Fl. species 4 (*Naumburgia*). For suggestions about literature see Bergen and Davis, *Laboratory and Field Manual of Botany*, p. 230.

The novice should find a good deal of help in understanding the structure of some of the more difficult flowers and fruits in the illustrations which accompany several families. Most of these have been redrawn for the present edition by Mr. E. N. Fischer of Boston.

J. Y. B.

CAMBRIDGE, MASSACHUSETTS

HOW TO USE THE KEY AND FLORA

In order to determine an unknown species, the student is first to make a careful examination of the plant in hand. After noting in a general way the appearance of the root, stem, and leaf, including a cross section of the stem, he should study the number of the parts of the flower, then make and draw a cross section and a lengthwise section of it. The kind of symmetry of the calyx and corolla, peculiarities in the shape, structure, or operation of the essential organs, such, for instance, as anthers discharging through chinks in the end, should be noted.

Next, the inquirer should look carefully through the key to the families. He is first to decide whether the plant in question is a Gymnosperm or an Angiosperm; if not a coniferous tree or shrub, it will of course belong to the latter division. He is then to settle the question whether it is a Monocotyledon or a Dicotyledon; then under what division of the group the plant comes; and, finally, to decide upon its family.

Turning now to the page at which the family is described, a rapid inspection of the characteristics of the genera will make it evident to which one the species under examination belongs. It may not infrequently prove that none of the genera described agree with the plant studied, and in that case the student must either consult a larger flora or rest satisfied with having determined the family to which his specimen belongs. The identification of the species, after

the genus has been reached, presents no difficulty in a little flora like the present one.

A single example may suffice to illustrate more in detail the manner of determining species. Suppose the student to have in hand a flowering specimen of lily of the valley. Turning to the key, page 5, it is evident from the statements concerning Gymnosperms that the plant does not belong under that head. Under Angiosperms it is clear, from the numerical plan of the flower (in threes) and the parallel-veined leaves, that the plant is a Monocotyledon. Among Monocotyledons three general groups are designated by as many numbers in parenthesis. The flower in hand belongs under (3) "Flowers not on a spadix." Under this head the choice is first between (*a*) "Carpels numerous and separate" and (*b*) "Carpels united." In the lily of the valley they are united. The next choice is between "* Perianth hypogynous" and "** Perianth not hypogynous." This flower is hypogynous. The families with hypogynous perianth are grouped under three divisions (distinguished by †, ††, ††† respectively), and of these the last, with its "Perianth actinomorphic, its divisions all alike or nearly so, petal-like," corresponds to the flower under examination and refers the student to "10. Lily Family, page 6." Turning to the key to the genera of the Lily family, page 31, two subfamilies are found. Since the plant is not a climber it belongs to "Subfamily I. Liliaceæ Proper."

This subfamily is divided into five groups designated by capital letters. The lily of the valley has an undivided style and springs from a rootstock, therefore it belongs to group B. Reading the descriptions under B, none is found to agree with the plant in hand until the next to the last is reached: "Leaves only 2, directly from the rootstock. Flowers in a raceme, bell-shaped, white, sweet-scented, *Convallaria*."

Referring now to the genus, it is found that there is only one species and that one agrees with the specimen in hand. It is therefore *Convallaria majalis,* and the name (as indicated by the L. which follows it) was given by the great Swedish naturalist, Linnæus.[1]

The author does not believe in spending much of the school time of a class upon identifying species, but would rather recommend comparative studies of as many plants of a group as are accessible, and making these studies thorough enough to bring out fully the idea of the family, the genus, and the species.[2] The descriptions in this flora may be used as a check on the cruder ones which the pupil is first to frame for himself.

[1] It will greatly simplify matters if the teacher throughout selects for examination only such species as are described in the flora.

[2] The teacher will find abundant suggestions for such a course in Spalding's *Introduction to Botany*, pp. 152–260.

KEY TO THE FAMILIES OF FLOWERING PLANTS DESCRIBED IN THIS FLORA

CLASS I

GYMNOSPERMS. Ovules not inclosed in an ovary.

Trees or shrubs. Leaves usually evergreen and needle-shaped, awl-shaped, or scale-like. Flowers monœcious or diœcious. Fruit a scaly cone, or sometimes appearing berry-like. 1. Pine Family, page 13

CLASS II

ANGIOSPERMS. Ovules inclosed in an ovary.

SUBCLASS I. — MONOCOTYLEDONS. Flowers usually with their parts in threes, never in fives. Leaves usually parallel-veined. Cotyledon 1.

	FAMILY	PAGE
(1) Flowers inclosed by chaffy bracts.		
Flowers 2-bracted. Leaves 2-ranked. Stem cylindrical	4. Grass	22
Flowers 1-bracted. Leaves 3-ranked. Stem triangular	5. Sedge	23
(2) Flowers on a spadix.		
Spadix slender, hairy, and bristly	2. Cat-Tail	20
Spadix fleshy	6. Arum	24
(3) Flowers not on a spadix.		
(*a*) Carpels usually numerous and nearly or entirely separate	3. Water Plantain	21
(*b*) Carpels united.		
* Perianth hypogynous or nearly so.		
† Perianth actinomorphic, its parts similar, green, or chaffy	9. Rush	30
†† Perianth of 2 sets, one sepal-like, the other petal-like.		
Style and stigma 1. Petals 3 or 2, soon disappearing	7. Spiderwort	26

	Family	Page
Styles or stigmas 3, separate. Petals 3, lasting several days. Leaves netted-veined . .	10. (*Trillium*) Lily .	30
Style 1, stigma 3-lobed or 6-toothed.		
Corolla not actinomorphic. Aquatic herbs with parallel-veined leaves	8. Pickerel Weed .	28
††† Perianth actinomorphic, its divisions all alike or nearly so, petal-like	10. Lily	30
** Perianth not hypogynous.		
Anthers 6	11. Amaryllis . .	43
Anthers 3	12. Iris	45
Anthers 1 or 2	13. Orchis . . .	47

SUBCLASS II. — DICOTYLEDONS. Flowers usually with their parts in fives or fours. Leaves netted-veined. Cotyledons 2.

I. Apetalous Division. Flowers without a corolla or without either calyx or corolla.[1]

A

	Family	Page
Flowers monœcious or diœcious, one or both sorts in catkins.		
(1) Staminate flowers in catkins, the pistillate ones solitary or clustered.		
Leaves pinnately compound	16. Walnut . . .	52
Leaves simple	18. Beech.	58
(2) Both kinds of flowers in catkins.		
(*a*) Leaves alternate.		
Ovaries in fruit becoming fleshy and combining into an aggregate fruit . . .	20. Mulberry . .	64
Fruit 1-seeded, a drupe or minute nut. Aromatic shrubs	15. Bayberry . .	51
Fruit a capsule, seeds with silky hairs . .	14. Willow . . .	48
Fruit a minute nut or akene. Mostly large shrubs or trees, not very aromatic . .	17. Birch	54
(*b*) Leaves opposite, small parasitic shrubs . .	23. Mistletoe . . .	68

B

Flowers not in catkins, both calyx and corolla wanting	45. Sycamore . .	113

[1] When only one floral envelope is present, this is said to be the calyx and the corolla is considered to be missing.

C

	Family	Page
Flowers not in catkins; calyx present, sometimes petal-like.		
(1) Trees or shrubs.		
Flowers not hypogynous; plants not climbing .	74. Dogwood . . .	175
Flowers not hypogynous; climbing plants . .	24. Dutchman's Pipe	68
Flowers hypogynous.		
Style single, not cleft, fruit a key (*Fraxinus*)	79. Olive	189
Style single, not cleft, fruit a drupe . . .	38. Laurel	95
Styles 2 or 2-cleft, fruit 1-celled	19. Elm	62
Styles 2 or 2-cleft, fruit 2-celled	59. Maple	151
Styles 3, each 2-cleft. Ovary 3-celled . . .	54. Spurge	145
(2) Herbs.		
Flowers not hypogynous; ovary 6-celled . . .	24. Dutchman's Pipe	68
Flowers not hypogynous; ovary 1-celled; flowers in umbel-like clusters	22. Sandalwood . .	67
Flowers hypogynous.		
(*a*) Ovary 1-celled.		
Stamens many	33. Buttercup . . .	83
Stamens few.		
Stipules sheathing the joints	25. Buckwheat . .	69
Stipules wanting.		
Rather fleshy herbs	26. Goosefoot . . .	72
Not fleshy.		
Ovules on a free central placenta; delicate, soft-leaved herbs. (*Stellaria*) . .	31. Pink	77
Ovule single, coarse herbs	27. Amaranth . . .	74
(*b*) Ovary several-celled.		
Small prostrate herb; leaves spatulate, whorled	29. Ice Plant . . .	76
Stipules present, not sheathing.		
Style single	21. Nettle	66
Styles 2	20. Mulberry . . .	64
Flowers hypogynous, ovary 3-celled	54. Spurge	145
Flowers hypogynous, ovary 5–10-celled; fruit a berry	28. Pokeweed . . .	75

II. Choripetalous Division. Calyx and corolla both present, the petals not united.

A

Stamens more than 10.	Family	Page
(1) Trees, shrubs, or woody vines.		
(*a*) Leaves alternate.		
* Ovary 1, simple.		
Fruit a drupe	46. Rose	113
** Ovary 1, compound; fruit dry.		
Ovary 5-celled, 1–2-seeded at maturity	64. Linden	157
Ovary 3-celled, many-seeded	69. Begonia	164
*** Ovary 1, compound; fruit fleshy	46. Rose	113
**** Ovaries numerous.		
† Leaves with stipules.		
Stamens inserted on the receptacle	35. Magnolia	92
Stamens many, monadelphous	65. Mallow	158
Stamens inserted on the calyx	46. Rose	113
†† Leaves not with stipules.		
Small trees	37. Papaw	94
(*b*) Leaves opposite; fruit dry.		
Ovary single, 3–5-celled	44. Saxifrage	109
Ovaries several, inclosed by the calyx tube	36. Calycanthus	94
(2) Herbs.		
(*a*) Ovary single, simple; fruit a berry	34. Barberry	91
(*b*) Ovaries several, simple.		
Stamens inserted on the receptacle	33. Buttercup	83
Stamens inserted on the calyx	46. Rose	113
(*c*) Ovary compound.		
Aquatic herbs, leaves flat	32. Water Lily	82
Marsh herbs, leaves tubular	43. Pitcher Plant	108
Terrestrial herbs.		
* Ovary 1-celled.		
Placentæ central, juice watery	30. Purslane	76
Placentæ parietal, juice milky or colored	39. Poppy	96
Placentæ 2, parietal	41. Caper	107
Placentæ 3 or more, parietal.		
Leaves alternate	42. Mignonette	108
Leaves opposite	66. St. John's-wort	160
Leaves apparently wanting; stems fleshy	70. Cactus	166
** Ovary several-celled; stamens monadelphous	65. Mallow	158
*** Ovary 3-celled; stamens not much if at all monadelphous; stems fleshy, juice acid	69. Begonia	164

B

Stamens not more than 10.

	Family	Page
(1) Trees, shrubs, or woody vines.		
(*a*) Fruit a drupe.		
Stamens 2, rarely 3–4	79. Olive	189
Stamens as many as the petals.		
Flowers bisexual.		
Stamens 4, alternate with the petals	74. Dogwood	175
Stamens 5, alternate with the petals	55. Sumac	148
Stamens 4–5, opposite the petals	62. Buckthorn	154
(*b*) Fruit a berry.		
Stamens alternate with the petals.		
Inserted on the calyx, leaves simple	44. Saxifrage	109
Inserted on a disk surrounding the ovary; leaves compound	72. Ginseng	169
Stamens opposite the petals	63. Grape or Vine	155
(*c*) Fruit a 2-seeded capsule or a key.		
Leaves compound	52. Rue	144
(*d*) Fruit a 2-celled, many-seeded capsule; flowers large, yellow	79. Olive	189
(*e*) Fruit a 3–5-celled capsule; flowers small, greenish, or brown-purple; leaves simple	57. Wahoo	150
(*f*) Fruit 5-lobed, the 5 carpels separating when ripe; flowers rather large, white, or of showy colors; leaves simple	48. Geranium	140
(*g*) Fruit a 1–3-celled capsule, leaves compound, flowers zygomorphic	60. Buckeye	152
(*h*) Fruit a 3-celled bladdery capsule, leaves compound, flowers actinomorphic	58. Bladder Nut	151
(*i*) Fruit a legume	47. Pea or Pulse	126
(2) Herbs.		
(*a*) Ovary single, 1-celled, simple or compound.		
* Corolla actinomorphic or nearly so.		
Sepals and petals 4–5; stamens 5, 10, or 12, distinct.		
Leaves alternate.		
Stigma single	47. Pea or Pulse	126
Stigmas 4 or 2	44. Saxifrage	109
Leaves opposite, punctate, flowers yellow	66. St. John's-wort	160
Leaves opposite, flowers white or red	31. Pink	77
Sepals and petals 4–5; stamens 5, united	68. Passion Flower	163
Sepals 2, petals 4–5	30. Purslane	76

	Family	Page
Sepals 6, stamens hypogynous, opposite the petals	34. Barberry . . .	91
** Corolla zygomorphic.		
Fruit a legume	47. Pea or Pulse . .	126
Fruit a capsule.		
Stamens 5	67. Violet	161
Stamens 6, in 2 sets	39. Poppy	96
(*b*) Ovary single, 2-5-celled, fruit usually dry.		
* Ovary 2-celled (or 2 carpels nearly separate).		
Flowers in umbels, stamens 5	73. Parsley . . .	170
Flowers not in umbels, petals 4 or 0, stamens 6	40. Mustard . . .	99
Flowers not in umbels, petals 5, stamens 10 .	44. Saxifrage . . .	109
Flowers not in umbels, petals 3, stamens 6 or 8	53. Polygala . . .	145
** Ovary a 4-celled capsule	71. Evening Primrose	168
*** Ovary of 3 nearly distinct lobes, which become thick and fleshy in fruit	50. Indian Cress . .	142
**** Ovary a 5-celled capsule.		
† Leaves simple.		
Parasitic white or yellowish herbs, or evergreen herbs, not parasitic, capsule many-seeded	75. Pyrola	177
Terrestrial, not much if at all fleshy, capsule 5–10-seeded	48. Geranium . . .	140
Terrestrial, stem fleshy and translucent, capsule elastic, several-seeded	61. Balsam	153
†† Leaves of 3 leaflets	49. Wood Sorrel . .	142
(*c*) Ovary of 5 principal cells, each more or less divided by a partition into 2 cells; seeds flattish, with a mucilaginous coating	51. Flax	143
(*d*) Ovary single, 2-5-celled; fruit a berry	72. Ginseng . . .	169
(*e*) Ovaries 2, seeds hairy-tufted	82. Milkweed . . .	194

III. Sympetalous Division. Calyx and corolla both present, the petals appearing more or less united.

(1) Trees, shrubs, or woody vines.		
(*a*) Leaves alternate.		
* Fruit splitting open.		
Fruit a legume	47. Pea or Pulse . .	146
Fruit a 5-celled capsule	76. Heath	179
** Fruit not splitting open, a drupe	56. Holly	149
*** Fruit a berry.		

	Family	Page
Ovary superior; seeds few, large	78. Ebony	188
Ovary superior; seeds many, small	89. Nightshade	214
Ovary inferior	76. Heath	179
(*b*) Leaves opposite.		
* Fruit a 2-celled, 2-seeded capsule	95. Madder	227
** Fruit a 2-celled, many-seeded capsule.		
Seeds large, winged	91. Bignonia	222
Seeds not winged except in *Diervilla;* shrubs	96. Honeysuckle	230
*** Fruit a 5-celled capsule	76. Heath	179
**** Fruit a drupe or berry.		
Fruit 1-2-seeded (in *Forsythia* many-seeded); stamens 2	79. Olive	189
Fruit 1-4-seeded; stamens 4	87. Verbena	207
Fruit 1-5-seeded; stamens 5	96. Honeysuckle	230
(2) Herbs.		
(*a*) Ovary superior, flowers regular.		
* Ovary separating into 2 distinct follicles.		
Style single, stamens distinct	81. Dogbane	192
Styles 2, stamens united.	82. Milkweed	194
** Ovary 1-celled.		
Fruit a legume	47. Pea or Pulse	126
Fruit a capsule.		
Leaves alternate.		
Stamens opposite the lobes of the corolla	77. Primrose	184
Stamens alternate with the lobes of the corolla	85. Waterleaf	201
Leaves opposite	80. Gentian	191
Leaves all reduced to mere scales, plants never green, root parasites	92. Broom Rape	223
**** Ovary 2-several-celled.		
Stamens 2 or 4	94. Plantain	225
Stamens 5, cells of the ovary 1-2-seeded.		
Fruit separating into 4 nutlets	86. Borage	203
Fruit a capsule	83. Morning-Glory	197
Stamens 5, cells of the ovary several-seeded.		
Stigma 1	89. Nightshade	214
Stigmas 3	84. Phlox	199
(*b*) Ovary superior, flowers zygomorphic.		
* Ovary 1-celled.		
Fruit a legume	47. Pea or Pulse	126

	Family	Page
** Ovary 2-4-celled.		
† Cells each 1-seeded.		
Ovary deeply 4-lobed	88. Mint	209
Ovary not deeply lobed.		
Stamens 2 or 4	87. Verbena	207
Stamens 8	53. Polygala	145
†† Cells each 2-several-seeded.		
Corolla lobes imbricate in the bud	90. Figwort	217
Corolla lobes convolute in the bud	93. Acanthus	224
(*c*) Ovary inferior.		
Flowers in an involucrate head	100. Composite	239
Flowers not in heads.		
Stamens 3.		
Leaves opposite	97. Valerian	235
Leaves alternate	98. Gourd	236
Stamens 4-5.		
Leaves alternate	99. Campanula	237
Leaves opposite or whorled	95. Madder	227

CLASS I. GYMNOSPERMS

Plants destitute of a closed ovary, style, or stigma. Ovules generally borne naked on a carpellary scale, which forms part of a cone. Cotyledons often several (Fig. 1).

1. PINACEÆ. Pine Family

Trees or shrubs with wood destitute of ducts, with resinous and aromatic juice. Leaves generally evergreen, and needle-shaped or awl-shaped. Flowers destitute of floral envelopes, monœcious or diœcious, the staminate ones consisting of catkin-like spikes of stamens and the pistillate ones consisting of ovule-bearing scales, arranged in spikes, which ripen into cones.

A

Each scale of the cone borne in the axil of a bract. Seeds 2, with wings.

Leaves evergreen, in bundles of 2–5. Pinus, I

Leaves evergreen, solitary, sessile, keeled on both surfaces. Picea, II

Leaves evergreen, solitary, petioled, flat. Tsuga, III

Leaves solitary, evergreen, flat above, keeled below. Abies, IV

Leaves clustered, deciduous, flat. Larix, V

B

Scales of the cone without bracts, cone becoming globular and woody. Leaves linear.

Leaves alternate, deciduous. Taxodium, VI

C

Scales of the cone few, without bracts. Leaves evergreen, generally scale-like or awl-shaped.

Cones dry and thin-scaled. Thuja, VII

Cones berry-like. Juniperus, VIII

I. PINUS L.

Sterile flowers somewhat resembling inconspicuous catkins, borne at the base of the young shoot of the season, each flower consisting of pollen-scales in spiral groups (Fig. 1, *2*). Fertile flower spikes consisting of spirally arranged carpel scales, each scale springing from the axil of a bract and bearing at its own base two ovules (Fig. 1, *3*). Fruit a cone, formed of the thickened carpellary scales, ripening the second autumn after the flower opens. Primary leaves, thin and chaffy bud scales, from the axils of which spring the bundles of 2–5 nearly persistent, needle-like, evergreen leaves, 1–15 in. long (Fig. 1).

1. P. Strobus L. WHITE PINE. A tall tree, 75–160 ft. high, much branched and spreading when growing in open ground, but often with few or no living branches below the height of 100 ft. when growing in dense forests. Leaves clustered in fives, slender, 3–4 in. long, smooth and pale or with a whitish bloom. Cones 5–6 in. long, not stout. The wood is soft, durable, does not readily warp, and is therefore very valuable for lumber. In light soil; commonest N.

2. P. Tæda L. LOBLOLLY PINE, OLDFIELD PINE. A large tree; bark very thick and deeply furrowed, becoming flaky with age; twigs scaly. Leaves in threes, 6–10 in. long, slender, very flexible; sheaths $\frac{2}{3}$–1 in. long. Cones solitary, oblong-conical, 3–5 in. long; scales thickened at the apex, the transverse ridge very prominent and armed with a short, stout, straight or recurved spine. Common, and often springing up in old fields; trunk containing a large proportion of sapwood; timber of little value for outside work.*[1]

3. P. rigida Mill. NORTHERN PITCH PINE. A stout tree, 30–80 ft. high, with rough, scaly bark. Leaves in threes, 3–5 in. long, stiff and flattened. Cones ovoid-conical, 2–3 in. long, their scales tipped with a short, abruptly curved spine. Wood hard, coarse, and resinous, mainly used for fuel. Poor, sandy soil, especially eastward.

[1] Descriptions followed by an asterisk are taken (more or less simplified) from Professor Tracy's flora in the *Southern States Edition.*

4. P. virginiana Mill. SCRUB PINE. A small tree, usually 20–30 ft. high, but sometimes much taller; bark of the trunk rough, nearly black; twigs smooth and with a bloom. Leaves in twos, 1–2 in.

FIG. 1. Scotch pine (*Pinus sylvestris*)

1, a twig showing: *a*, staminate catkins; *b*, pistillate catkins; *c*, a cone; *d*, needles. 2, an anther: *a*, side view; *b*, outer surface. 3, a carpel scale: *a*, inner surface; *b*, outer surface. 4, *a* a cone scale, *b* a seed wing, and *c* a seed. 5, section of a seed, showing the embryo. 1 is natural size; parts 2, 3, and 5 are magnified by the amount indicated by comparison with the vertical line alongside each. (After Wossidlo)

long, rigid, sheaths very short. Staminate catkins dull, yellowish-purple, 1 in. long. Cones solitary, short-peduncled, often reflexed, ellipsoid-conic, about 2 in. long; scales thickened at the apex and

armed with a slender, straight or recurved prickle. On dry, sandy soil; wood light, soft, weak, and of little value.*

5. P. sylvestris L. Scotch Pine (wrongly called Scotch Fir). A medium-sized tree, with the older bark reddish and scaly. Leaves in twos, $1\frac{1}{2}$–$2\frac{1}{2}$ in. long. Cones rather small and tapering (Fig 1, *1, c*). Cultivated from Europe.

6. P. resinosa Ait. Red Pine, Norway Pine. A tall, rather slender tree, with bark reddish-brown and moderately smooth. Leaves in twos, slender, and 5–6 in. long. Cones borne at the ends of the branches, smooth, about 2 in. long. A valuable timber tree, which often grows in small, scattered clumps; wood firm, pale red, and not very resinous; used in house and bridge building, and for masts and spars.

7. P. palustris Mill. Long-Leaved Pine. A large tree; bark thin-scaled, wood very resinous, old trees with only a few spreading branches near the top. Leaves in threes, 10–15 in. long. Sheaths 1–$1\frac{1}{4}$ in. long, crowded near the ends of very scaly twigs. Staminate catkins 2–3 in. long, bright purple, conspicuous. Cones terminal, ellipsoid-conical, 6–10 in. long, diameter 2–3 in. before opening, 4–6 in. when fully opened; scales much thickened at the apex and armed with a short recurved spine at the end. The most common tree in the pine barrens; wood hard, strong, and durable, especially valuable for floors and inside work.*

II. PICEA Link

Sterile flowers generally axillary (sometimes terminal), borne on the twigs of the preceding year. Fertile flowers terminal. Fruit a nodding, thin-scaled cone, ripening in the first autumn. Leaves evergreen, needle-shaped, four-angled, scattered or spirally arranged.

1. P. mariana BSP. Black Spruce. A small tree, usually only 20 or 30 ft. high, often less. Leaves strongly 4-angled, bluish-green, and glaucous, $\frac{1}{4}$–$\frac{3}{4}$ in. long. Cones ovoid, pointed, $\frac{1}{2}$–$1\frac{1}{2}$ in., usually about 1 in. long, persisting sometimes for 20–30 years. Wood of little value except for paper pulp. The tree is especially abundant northward and is of common occurrence in peat bogs.

2. P. rubra Dietrich. Red Spruce. A large tree, 70–80 or even 100 or more feet high, of strict conical habit. Leaves dark green or yellowish and glossy, $\frac{1}{2}$–$\frac{5}{8}$ in. long. Cones ovoid-oblong, acute, usually $1\frac{1}{2}$–2 in. long, mostly falling the first year. This is the principal timber spruce of the northeastern United States, and furnishes much rather tough lumber for use in floor joists, scantling, and similar purposes.

3. P. canadensis BSP. WHITE SPRUCE, SKUNK SPRUCE, CAT SPRUCE. A tall, rather conical tree, 60–70 ft. high. Leaves pale and with a bloom sometimes $\frac{3}{4}$ in. long. Cones cylindrical, with rounded ends, about 2 in. long, falling inside of one year. A handsome tree, valuable for timber, ranging far northward.

4. P. Abies Karst. NORWAY SPRUCE. A large tree. Leaves dark green, $\frac{3}{4}$–1 in. long. Cones 5–7 in. long. Cultivated from Europe.

III. TSUGA Carrière

Sterile flowers, clusters of stamens springing from the axils of leaves of the preceding year. Cones terminal, on twigs of the preceding year, drooping, thin-scaled, ripening the first year. Leaves minutely petioled, short, flat, white beneath, 2-ranked.

1. T. canadensis Carrière. HEMLOCK. A large tree, in age branchless below when growing in dense woods. When young the spray is very graceful and abundant. Leaves short-linear. Cones $\frac{3}{4}$ in. or less in length. The wood is coarse and splintery, but useful for fences and other rough work. The thick reddish bark is of great value for tanning.

IV. ABIES Hill

Sterile flowers from axils of leaves of the preceding year. Cones erect, on the sides of the branches, with deciduous scales, ripening the first year. Leaves scattered, but on horizontal branches appearing 2-ranked, flat above, silvery, and with a prominent midrib below.

1. A. balsamea Mill. BALSAM FIR. A slender tree, 50–60 ft., occasionally 80 ft., high, with dense foliage. Leaves narrowly linear, less than 1 in. long. Cones violet-colored until old, cylindrical, 2–4 in. long. The bark contains many large blisters, filled with the well-know Canada balsam. The wood is brittle and of little value.

V. LARIX Mill.

Flower spikes short, opening in early spring, before the leaves; the fertile ones, while still young, of a beautiful crimson color. Fruit a small cone, with thin scales. Leaves none of them scaly, but all needle-shaped, soft, deciduous, very numerous, in little brush-like bundles.

1. L. laricina Koch. AMERICAN LARCH, TAMARACK, HACKMATACK (wrongly, but quite generally, called Cypress and Juniper). A tall, slender tree, 30–100 ft. high. Leaves slender and less than 1 in. long, very pale bluish-green. Cones $\frac{1}{2}$–$\frac{3}{4}$ in. long, few-scaled. Wood hard, tough, and heavy, of considerable use for shipbuilding.

2. L. decidua Mill. EUROPEAN LARCH. Leaves bright green and longer. Cones longer than in the preceding species and many-scaled. Cultivated from Europe.

VI. TAXODIUM Richard

Trees. Leaves spreading so as to appear 2-ranked, deciduous. Flowers monœcious, appearing before the leaves; staminate ones numerous, globose, forming long, terminal, drooping, panicled spikes; anthers 2–5-celled. Pistillate flowers single or in pairs, bractless, the peltate scales 2-ovuled. Cone globose; the very thick woody scales angular, separating at maturity. Seeds 3-angled, pyramidal.*

1. T. distichum Richard. BALD CYPRESS. A very large tree; bark dark brown, rough, fibrous; many of the twigs deciduous with the leaves. Leaves alternate, opposite, or whorled, 2-ranked, flat, linear, $\frac{1}{2}$–$\frac{3}{4}$ in. long. Cones terminal, globose, about 1 in. in diameter; ends of the scales much thickened, wrinkled, and with a distinct triangular marking. Common in swamps and on the borders of streams; wood reddish, soft, light; specially valued for shingles and fence posts, and for boat building.*

VII. THUJA L.

Flowers small, terminal, monœcious, on different branches. Stamens each consisting of a scale-like portion bearing 4 anther-like cells. Pistillate flowers consisting of a few overlapping scales which ripen into a small, loose cone. Leaves evergreen, opposite, and closely overlapping on the stem, of two kinds, those on the more rapidly growing twigs awl-shaped, the others mere scales.

1. T. occidentalis L. ARBOR VITÆ, CEDAR. A small tree, 20–50 ft. high, with soft, fibrous bark. Leaves mostly awl-shaped and blunt. Cones ellipsoidal, their scales 2-seeded. Grows on rocky ledges, but reaches its greatest size in cool cedar swamps. Wood soft, yellowish, fragrant, durable, prized for shingles and fence posts.

VIII. JUNIPERUS L.

Flowers very small, lateral, diœcious, or sometimes monœcious. Scales of the staminate flower shield-shaped, with 3–6 anther cells. Fertile flowers with 3–6 fleshy scales which unite into a berry-like, 1–3-seeded fruit. Leaves awl-shaped or scale-shaped.

1. **J. communis** L. JUNIPER. A low, spreading shrub (one variety prostrate in circular masses). Leaves linear-awl-shaped, with needle-like points, each marked with a distinct stripe of bloom along the center of the upper surface, borne in whorls of three. Fruit a dark blue aromatic berry, $\frac{1}{4}$ in. or more in diameter. Grows in dry pastures and on sterile hillsides N.

2. **J. virginiana** L. RED CEDAR, SAVIN. Ranges in size and shape from a low, rather erect shrub, to a conical tree 90 ft. high. Leaves of two kinds, those on the rapidly growing shoots awl-shaped and pointed, those on the shortest twigs scale-shaped, obtuse, or nearly so, and closely appressed to the stem. Fruit small, bluish, with a white bloom. Found all the way from British America to Florida. Wood soft, fragrant, reddish, exceedingly durable in the ground, valued for the manufacture of moth-proof chests and especially for lead pencils.

CLASS II. ANGIOSPERMS

Plants with a closed ovary, in which the seeds are matured. Cotyledons 1 or 2.

SUBCLASS I. MONOCOTYLEDONOUS PLANTS

Stems with the fibrovascular bundles scattered among the parenchyma cells; in perennial plants no annual rings of wood. Leaves usually parallel-veined, alternate, nearly always entire. Parts of the flower generally in threes (never in fives). Cotyledon 1.

2. TYPHACEÆ. Cat-Tail Family

Perennial marsh or aquatic plants. Rootstock stout, creeping; stem simple, cylindrical, erect. Leaves simple, strap-shaped, sheathing at the base, nerved and striate. Flowers monœcious, in a single terminal spike, staminate part of the spike uppermost, each part subtended by spathe-like deciduous bracts. Perianth of fine bristles. Staminate flowers sessile, stamens 2–7; filaments connate, subtended by minute bracts. Pistillate flowers short-pediceled. Ovary 1–2-celled; styles 1–2. Fruit small, nut-like.*

TYPHA L.

Characters of the family.

1. **T. latifolia** L. Cat-Tail. Stem erect, jointed below, 5–8 ft. high. Leaves nearly as long as the stem, about 1 in. wide, netted and with a bloom. Spike cylindrical, dark brown or black; staminate portion above the pistillate, usually without any interval between them, each 4–8 in. long and about 1 in. in diameter. Fruit furrowed. Common in marshes and shallow ponds.*

3. ALISMACEÆ. Water Plantain Family

Annual or perennial marsh herbs, usually with creeping runners or rootstocks. Stems scape-like. Leaves long-petioled, sheathing at the base; petiole rounded; blade nerved, netted, or sometimes wanting. Flowers in racemes or panicles, bisexual, monœcious or diœcious; pedicels in bracted whorls. Sepals 3, persistent; petals 3 or wanting. Stamens 6 or more. Ovaries few or many, 1-celled, 1-seeded; style short or none. Fruit a 1-seeded akene.*

I. SAGITTARIA L

Perennial; rootstocks mostly knobby or tuber-bearing. Scapes erect or decumbent. Leaves long-petioled, sheathing at the base, the blade round and netted, or wanting. Flowers monœcious or diœcious, racemed in 3-bracted whorls of threes, the upper flowers usually staminate. Sepals 3, persistent; petals 3, withering-persistent or deciduous. Stamens few or many. Ovaries in globose heads, 1-ovuled; style short, persistent. Fruit a subglobose head of flattened akenes.*

1. S. latifolia Willd. Broad-Leaved Arrowhead. Leaves very variable in size and shape, from broadly sagittate to linear, those growing on the drier soil being usually the broader; petioles 6–30 in. long. Scape smooth or slightly downy, 6–36 in. high; bracts acute. Flowers monœcious or sometimes diœcious, white, 1 in. or more in width; pedicels of the staminate flowers twice the length of those of the fertile flowers. Filaments long, smooth, and slender. Akenes with beak nearly horizontal. Ditches and muddy places.*

2. S. graminea Michx. Grass-Leaved Sagittaria. Leaves long-petioled, lanceolate, or elliptical, and acute at each end, 3–5-nerved, or often linear, the earlier often reduced to flattened petioles. Scape slender, usually longer than the leaves, simple, weak, often prostrate in fruit; bracts small, ovate, connate at the base. Flowers monœcious or diœcious, on long, thread-like pedicels, about ½ in. wide. Stamens 10–20, filaments downy. Akenes nearly beakless. In ditches and shallow pools.*

II. ALISMA L.

Annual or perennial herbs. Leaves erect or floating, blades prominently ribbed and netted, or even pinnately veined.

Scapes erect, becoming longer than the leaves, cylindrical, spongy. Flowers bisexual, in paniculate, 3-bracted umbels, small, white or pink. Stamens 6–9. Ovaries numerous in one or more whorls on a flat receptacle. Fruit 1-seeded akenes which are ribbed on the back and sides.*

1. A. Plantago-aquatica L. WATER PLANTAIN. Perennial; root fibrous. Leaves ovate or somewhat cordate, 5–7-nerved when erect, floating leaves narrower and sometimes linear. Scapes usually single; panicle 1–2 ft. long; flowering branches whorled, subtended by three narrow, striate bracts; pedicels slender, elongated. Ovaries 15–20 in a single whorl; base of the short style persistent, forming a beak at the inner angle of the akene. Akenes obliquely obovate, 2–3-keeled on the back. Common in ponds and muddy places.*

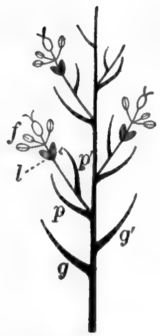


FIG. 2. Diagrammatic representation of a several-flowered grass spikelet

g, *g'*, the glumes; *p*, *p'*, the palets; *l*, lodicules; *f*, a flower. The axis is much lengthened, to separate the flowers. (After Schimper)

FIG. 3. Spike-like panicle of vernal grass (*Anthoxanthum*)

a, mature anthers. (Slightly enlarged)

4. GRAMINEÆ. GRASS FAMILY

Mostly herbs, with usually hollow stems, closed and enlarged at the nodes. Leaves alternate, in two ranks, with sheathing bases, which are split open on the side opposite the blade. Flowers nearly or quite destitute of floral envelopes, solitary, and borne in the axils of scaly bracts, which are arranged in two ranks

overlapping each other on 1–many-flowered *spikelets;* these are variously grouped in spikes, panicles, and so on. Fruit

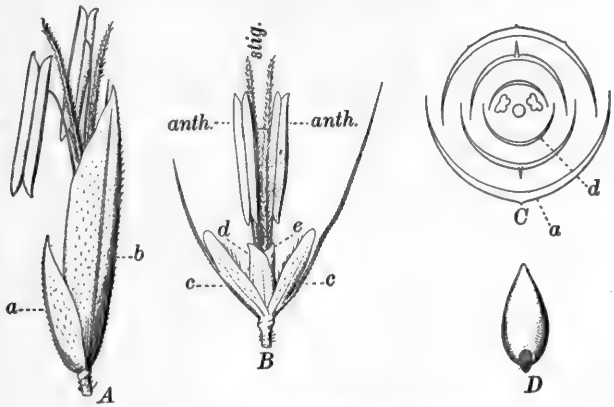


Fig. 4. Vernal grass (*Anthoxanthum*)

A, a one-flowered spikelet: *a*, *b*, the outer empty glumes. *B*, a spikelet with the outer glumes removed: *c*, *c*, the inner empty glumes (neuter flowers) with long, bristle-shaped appendages; *d*, *e*, palets; *anth.*, anthers; *stig.*, stigmas. *C*, diagram of cross section of a spikelet: *a*, glume; *d*, palet. *D*, a fruit. (All magnified.) (After Cosson and De Saint-Pierre)

a grain. (The family is too difficult for the beginner, but the structure and grouping of the flowers may be gathered from a careful study of Figs. 2, 3, 4.)

5. CYPERACEÆ. Sedge Family

Grass-like or rush-like herbs, with solid, usually triangular, stems, growing in tufts. The sheathing base of the generally 3-ranked leaves, when present, is not slit as in grasses. The flowers are usually somewhat less inclosed by bracts than those of grasses; the perianth is absent or rudimentary; stamens generally 3; style 2-cleft or 3-cleft.

The flower cluster and the flower of a sedge may be understood from an inspection of Fig. 5.

The species are even more difficult to determine than those of grasses.

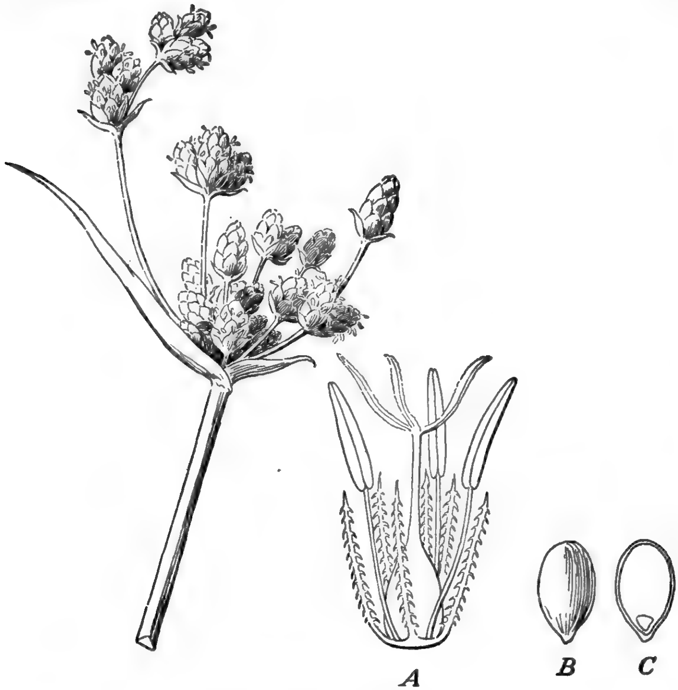


FIG. 5. Inflorescence, flower, and seed, of a sedge
(Great Bulrush, *Scirpus lacustris*)

A, magnified flower, surrounded by a perianth of hypogynous bristles; *B*, the seed; *C*, section of the seed, showing the small embryo inclosed in the base of the endosperm. (After Lindley)

6. ARACEÆ. ARUM FAMILY

Perennial herbs, with pungent or acrid juice. Leaves often netted-veined. Small, unisexual or bisexual flowers, clustered

along a peculiar fleshy spike called a *spadix*, and frequently more or less covered by a large, hood-like bract called a *spathe*. Perianth, when present, of 4–6 parts; often wanting. Fruit usually a berry.

I. ARISÆMA Martius

Perennial herbs, springing from a corm or a tuberous rootstock. Spathe rolled up at base. Summit of spadix naked, the lower part flower-bearing; staminate flowers above, pistillate ones below. Stigma flat. Ovary 1-celled. Berry 1–few-seeded.

1. A. triphyllum Schott. INDIAN TURNIP, JACK-IN-THE-PULPIT. Leaves generally 2, each of 3 elliptical-ovate, pointed leaflets. Spadix club-shaped, bearing usually only one kind of fully developed flowers; that is, full-sized pistillate and rudimentary staminate ones, or the reverse. Spathe much longer than the spadix, and covering it like a hood. Corm turnip-like, but much wrinkled, very starchy, and filled with intensely burning juice.

2. A. Dracontium Schott. GREEN DRAGON, DRAGON ROOT. Leaf usually single, divided into 7–11 rather narrow, pointed leaflets; spadix tapering to a long, slender point, often bearing fully developed staminate and pistillate flowers.

II. SYMPLOCARPUS Salisb. (SPATHYEMA)

Rootstock very stout, with many long, cylindrical roots. Leaves clustered, very large, and entire. Spathe shell-shaped, very thick. Spadix globular, thickly covered with bisexual flowers. Sepals 4. Stamens 4. Style 4-angled. Fruit globular or ellipsoidal, with the seeds slightly buried in the enlarged spadix.

Coarse, stemless herbs, with a powerful scent like that of the skunk and of onions.

1. S. fœtidus Nutt. SKUNK CABBAGE. Leaves many, slightly petioled, 1–2 ft. long, appearing after the flowers. The latter are usually seen before the ground is wholly free from frost, often earlier than any other flower. Bogs and wet meadows, very common N.

III. ACORUS L.

Rootstocks horizontal, long, and moderately stout, aromatic. Leaves long, upright, sword-shaped. Spathe much like the

leaves. Spadix projecting from the edge of the spathe, consisting of numerous bisexual flowers. Sepals 6. Stamens 6. Ovary 2–3-celled, with numerous ovules. Fruit 1–few-seeded.

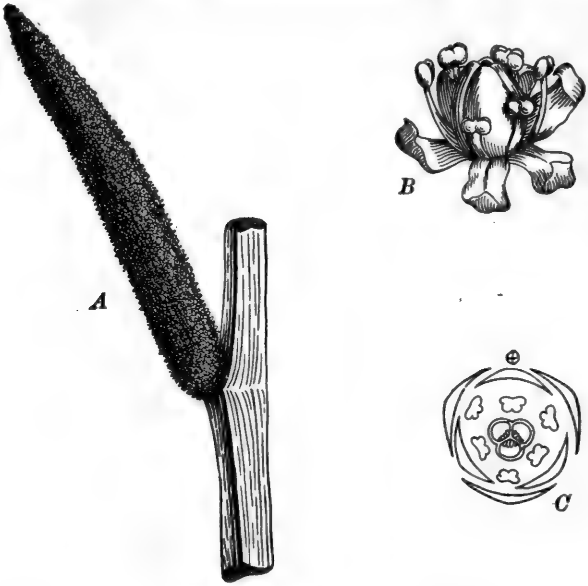


Fig. 6. *Acorus Calamus*

***A*, spadix; *B*, a single flower, enlarged; *C*, diagram of flower, enlarged. (After Schimper)**

1. **A. Calamus** L. Sweet Flag. Scape with a long, leaf-like prolongation (spathe) beyond the green, very closely flowered spadix. Along borders of brooks and swamps.

The rootstocks furnish the well-known calamus or "sweet flag root" sold everywhere by druggists.

7. COMMELINACEÆ. Spiderwort Family

Herbs, with slimy or mucilaginous juice; stems somewhat succulent, jointed, leafy, simple or branched. Leaves simple, succulent, narrow, entire, sheathing at the base, sheaths entire

or split. Flowers in terminal cymes or umbels, bisexual, often zygomorphic. Sepals 3, persistent, foliaceous or colored. Petals 3, soon falling or liquefying. Stamens 6 or fewer, often some of them abortive. Ovary 2–3-celled; style single; stigma entire or 3-lobed. Fruit a 2–3-celled, 2–3-valved capsule; seeds solitary or several in each cell.*

I. TRADESCANTIA L.

Perennial, stem simple or branched. Leaves very narrow. Flowers in terminal and axillary bracted umbels, actinomorphic, 1 in. broad. Sepals 3, herbaceous. Petals 3, soon falling, or liquefying to jelly. Stamens 6, sometimes 3 shorter than the others; filaments bearded or smooth. Ovary 3-celled, with 2 ovules in each cell; pedicels recurved in fruit. Capsule 3-celled, 3-valved, 3–6-seeded.*

1. T. virginiana L. SPIDERWORT. Stem erect, stout, smooth, or with long, soft hairs, 1–2 ft. high. Leaves linear, keeled, often purple-veined, long, taper-pointed, 1 ft. or more in length. Bracts similar to the leaves. Umbels sessile, 2–many-flowered, flowers in 2 rows in the bud. Petals blue or purple, twice as long as the sepals. Stamens blue, filaments densely bearded. Capsule ovoid or oblong. On dry, sandy soil.*

2. T. pilosa Lehm. HAIRY SPIDERWORT. Stem stout, erect or zigzag, branched, with long, soft hairs, or nearly smooth, 1–2 ft. high. Leaves linear-oblong, taper-pointed at the apex, narrowed at the base, hairy on both sides. Umbels axillary and terminal, many-flowered. Pedicels and sepals with soft, glandular hairs. Flowers blue or purple, $\frac{3}{4}$–1 in. wide. Seeds pitted. In rich soil.*

II. COMMELINA L.

Annual or perennial, stem branching, erect or procumbent, smooth or downy. Leaves petioled or sessile, entire, the floral ones heart-shaped, folded, and forming a spathe inclosing the base of the cymes. Flowers not actinomorphic. Sepals mostly colored, 1 of them smaller. Petals blue, unequal, 2 of them kidney-shaped and long-clawed, the third one smaller. Stamens 6, only 3 of them fertile; filaments smooth. Capsule 1–3-celled; seeds 1–2 in each cell.*

1. C. virginica L. VIRGINIA DAYFLOWER. Stem erect, downy, 1–2 ft. high. Leaves lanceolate to oblong-lanceolate, taper-pointed, 3–5 in. long, somewhat rough above; sheaths inflated, hairy, the opening often fringed. Spathes containing a slimy secretion. Flowers 1 in. wide, the odd petal lanceolate. Capsule 3-seeded, the dorsal cell not splitting open. On moist, sandy soil.*

III. ZEBRINA Schnizl.

Trailing or slightly climbing herbs. Leaves often striped. Flowers usually in pairs. Calyx with a short tube, regularly or irregularly 3-parted. Corolla nearly actinomorphic, with tube longer than the calyx. Filaments naked or bearded. Ovary 3-celled, 3–6-ovuled.

1. Z. pendula Schnizl. WANDERING JEW. Stems perennial, prostrate or nearly so, branching freely, rooting easily at the nodes. Leaves somewhat succulent, lance-ovate or oblong, crimson beneath, green or dark purplish above, often with two wide silvery stripes. Cultivated from Mexico.

8. PONTEDERIACEÆ. PICKEREL-WEED FAMILY

Perennial marsh or aquatic herbs, stems simple or branched, succulent. Leaves simple, alternate. Flowers solitary or spiked, each subtended by a leaf-like spathe, perfect, mostly not actinomorphic. Perianth corolla-like, 6-parted. Stamens 3 or 6, unequal, inserted irregularly in the tube or throat of the perianth. Ovary superior, 1- or 3-celled; style single; stigma entire or toothed. Fruit a 1-seeded utricle.*

PONTEDERIA L.

Stem erect, from a thick, creeping rootstock, bearing a single leaf above the middle and several sheathing, bract-like leaves at its base. Radical leaves numerous, thick, parallel-veined. Petiole long, from a sheathing base. Flowers in terminal spikes. Perianth 2-lipped, lobes of the upper lip ovate, of the lower oblong, spreading. Stamens 6, the 3 upper short and often imperfect, the 3 lower protruding. Ovary 3-celled,

A Fig. 7. Rushes

A, plant of *Juncus tenuis*, one half natural size; *B*, flower of same, magnified; *C*, fruit magnified; *D*, flower of wood rush (*Luzula*), magnified; (*D*, after Warming)

but only 1 cell ovule-bearing; the 1-seeded utricle inclosed by the base of the perianth.*

1. **P. cordata** L. Pickerel Weed. Stem stout, erect, 2–4 ft. high. Leaves long, from heart-shaped to lanceolate and often halberd-shaped; apex and basal lobes obtuse, finely nerved. Spike dense, 2–4 in. long; peduncles inclosed by the spathe. Perianth hairy, blue, the upper lip with 2 yellow spots; tube 6-ribbed, curved, rather longer than the lobes. Ovary oblong. In ponds and slow streams.*

9. JUNCACEÆ. Rush Family

Grass-like perennial or annual herbs, mostly growing on wet soil. Stems mostly erect but sometimes creeping, simple or branched, naked or leafy and jointed. Leaves cylindrical, sheathing at the base, very slender and pointed or flattened and grass-like. Flowers in cymes or panicles, which may be very loose and spreading, or so compact as to form a head, sometimes with a rigid scape prolonged beyond the flower cluster. Flowers usually bracted. Perianth of 6 nearly equal, scale-like, persistent divisions. Stamens 3 or 6, inserted on the base of the perianth. Ovary free, 1- or 3-celled, many-ovuled; style single; stigmas 3, usually hairy. Fruit a 1- or 3-celled, 3–many-seeded capsule. [Most species flower late in the season, and their identification is too difficult for one without considerable experience.]*

10. LILIACEÆ. Lily Family

Mostly herbs. Flowers actinomorphic. Perianth free from the ovary. Stamens nearly always 6, one before each division of the perianth. Ovary usually 3-celled; fruit a pod or berry, few–many-seeded.

Except in the genus Trillium the divisions of the perianth are colored nearly alike.

SUBFAMILY I. LILIACEÆ PROPER

Not tendril climbers, rarely diœcious.

A

Styles or sessile stigmas 3, more or less separate.

Leaves flat, lanceolate, or spatulate. Flowers diœcious, showy. Chamælirium, I

Leaves grass-like. Flowers bisexual, showy. Amianthium, II

Leaves 3-ranked, strongly nerved and plaited. Flowers somewhat monœcious, small. Veratrum, III

B

Style undivided (in No. XXIII, 3 sessile stigmas). Plants from rootstocks.

Leaves perfoliate. Flowers solitary, drooping, yellow. Uvularia, IV

Leaves broad, clasping. Flowers solitary or nearly so, drooping, yellow. Oakesia, V

Leaves scale-like. Thread-like branches borne in their axils. Flowers small, bell-shaped. Asparagus, XVIII

Leaves several–many, sessile or clasping, alternate. Flowers small, 6-parted, white, in a terminal simple or compound raceme. Smilacina, XIX

Leaves only 2–3, sessile or slightly petioled. Flowers very small, 4-parted, solitary or in a small terminal cluster. Maianthemum, XX

Leaves clasping. Flowers solitary or in pairs, greenish-white or rose-purple, borne on pedicels abruptly bent near the middle. Streptopus, XXI

Leaves nearly sessile or partly clasping. Flowers axillary, greenish, on pedicels jointed near the flower. Polygonatum, XXII

Leaves only 2, directly from the rootstock. Flowers in a raceme, bell-shaped, white, sweet-scented. Convallaria, XXIII

Leaves 3, netted-veined. Flower single, large, terminal. Trillium, XXIV

C

Style undivided. Plants from fibrous roots.

Flowers yellow or orange. Hemerocallis, VIII
Flowers white. Yucca, XVII

D

Style usually undivided. Plants from coated or solid-looking bulbs.

Leafy-stemmed plants. Flowers large, solitary, or apparently umbeled. Fritillaria, X

Apparently stemless plants.

(*a*) Plants with the smell of onions or garlic. Flowers umbeled. Allium, VI
(*b*) Plants scentless. Flowers umbeled. Nothoscordum, VII
(*c*) Flower solitary, erect, large. Tulipa, XII
(*d*) Flower solitary, nodding. Erythronium, XI
(*e*) Flowers racemed. Perianth with hardly any tube. Stigma a single knob. Scilla, XIII
(*f*) Flowers racemed. Perianth with hardly any tube. Stigma 3-cleft. Camassia, XIV
(*g*) Flowers corymbed. Perianth with hardly any tube. Leaves linear. Ornithogalum, XV
(*h*) Flowers racemed. Perianth with a tube. Leaves lance-linear. Hyacinthus, XVI

E

Style undivided. Plants from scaly bulbs. Lilium, IX

SUBFAMILY II. SMILACEÆ

Climbers, often tendril-bearing. Flowers diœcious. Smilax, XXV

I. CHAMÆLIRIUM Willd.

Rootstock short and thick, bitter. Stem simple, erect, leafy, smooth. Lower leaves spatulate to obovate, the stem leaves narrower. Flowers small, white, in a spike-like raceme, diœcious. Perianth of 6 linear-spatulate segments. Stamens 6, filaments longer than the perianth. Ovary 3-celled; styles 3. Fruit an ovoid, 3-angled, many-seeded capsule.*

1. **C. luteum** Gray. UNICORN ROOT, DEVIL'S BIT. Stem furrowed, staminate plants 1–2 ft. high, pistillate taller, often 3 ft. or more. Lower leaves obovate, clustered, the upper small and bract-like. Staminate racemes slender and drooping, the pistillate erect. Flowers short-pediceled. Capsule 3-valved, seeds linear-oblong, winged at the ends. On low ground.*

II. AMIANTHIUM Gray. (CHROSPERMA)

Stem simple, glabrous, erect from a bulbous base. Leaves long and slender. Flowers white, in a simple terminal raceme, bisexual. Perianth of 6 segments which are sessile and glandless. Stamens 6, somewhat perigynous. Ovary 3-lobed, 3-celled; fruit a dehiscent, 3-lobed capsule, the lobes becoming awl-shaped by the persistent style bases; cells few-seeded.*

1. **A. muscætoxicum** Gray. FLY POISON. Bulb ovoid or oblong. Stem somewhat angled below, 1–3 ft. high. Lower leaves strap-shaped, channeled, the upper small and bract-like. Raceme dense, cylindrical, pedicels from the axils of minute ovate bracts. Perianth segments ovate, white, becoming greenish, nearly as long as the slender stamens. Styles spreading. Capsule with divergent lobes; seeds ovoid, red. In rich woods.*

III. VERATRUM L.

Simple-stemmed perennials. Roots fibrous, from the thickened base of the stem, poisonous, emetic. Leaves 3-ranked, plaited, and veiny. Flowers panicled, greenish or brownish. Sepals 6, spreading, nearly hypogynous. Stamens shorter than the perianth, and somewhat perigynous. Ovary of 3 carpels united at base. Fruit a few-seeded capsule, splitting into 3 parts.

1. **V. viride** Ait. WHITE HELLEBORE, INDIAN POKE. Stem stout, 2–7 ft. high, very leafy. Flowers very numerous, in a panicle, composed of spike-like racemes. Sepals yellowish-green. Wet meadows and brooksides.

2. **V. Woodii** Robbins. Stem slender, 2–5 ft. high, not very leafy. Flowers in a long, narrow panicle. Sepals greenish-purple or almost black. Woods and dry hillsides.

IV. UVULARIA L.

Rather low plants with short rootstocks. Leaves alternate, broad, and parallel-veined. Flowers yellow or yellowish,

drooping, borne singly at the end of the forking stem. Perianth of 6 similar and separate narrow spatulate sepals, each grooved and nectar-bearing inside toward the base. Stamens 6, with linear anthers, which are much longer than the filaments. Style 3-cleft. Pod 3-lobed, 3-celled, few-seeded.

1. **U. perfoliata** L. Mealy Bellwort. Leaves much as in the preceding species. Flowers very pale yellow, with shining grains on the inner surfaces of the twisted sepals; anthers sharp-pointed. Plant about two-thirds the size of the preceding.

2. **U. grandiflora** Sm. Larger Bellwort. Leaves oblong, with the base clasping the stem so as to make it appear to run through the leaf a little way from the base. Flowers greenish-yellow, 1½ in. long; anthers obtuse. A leafy plant, 1–2 ft. high.

V. OAKESIA Wats.

Plants with much the aspect of the preceding genus, but with merely sessile leaves, triangular winged pods, and slender, creeping rootstocks.

1. **O. sessilifolia** Wats. Wild Oats, Straw Lilies. Stem slender, zigzag. Leaves lance-oval, thin, smooth, pale beneath, 1–1½ in. long. Flower cream color, nearly 1 in. long.

VI. ALLIUM L.

Herbs appearing stemless from coated bulbs with the characteristic odor of onions. Bulbs solitary or clustered. Leaves narrowly linear or slender-tubular, with a bloom. Flowers small, on slender pedicels, in terminal umbels on naked scapes, the umbels often bracted or inclosed in a spathe. Perianth 6-parted, persistent; stamens 6, somewhat perigynous, filaments filiform or dilated below. Ovary sessile, 3-celled; style thread-like, jointed; stigma entire. Fruit a 3-celled, 3-valved, few-seeded capsule. Flowers sometimes changed into bulblets.*

1. **A. reticulatum** Don. Resembling *A. Nuttallii*, but with larger bulbs. Leaves narrowly linear. Scape slender; bracts usually 2, taper-pointed; pedicels slender, ¼–½ in. long. Flowers white or pink; segments of the perianth thin. Capsule crested. W.

2. **A. Nuttallii** Wats. Bulbs ovoid, their coats with a fibrous network. Leaves basal, narrowly linear. Scape 4–8 in. high; bracts

3 or 2; pedicels $\frac{1}{3}$–$\frac{1}{2}$ in. long. Flowers rose color or white, the segments of the perianth becoming rigid in the fruit. On prairies W. and S.W.

3. A. canadense L. MEADOW GARLIC. Bulbs ovoid, the outer coats of white and thin, dry, netted fibers. Leaves narrowly linear, flat, or concave above. Scape cylindrical, 1 ft. high. Bracts of the umbel 2–3, ovate, acuminate; umbel consisting mostly of sessile bulblets. The few flowers long-pediceled, rose-colored. Perianth about as long as the stamens. Filaments dilated below. Capsule shorter than the perianth, 6-toothed, ovules 2 in each cell. On moist soil.*

4. A. mutabile Michx. WILD ONION. Bulbs ovoid, their coats with a very prominent fibrous network. Leaves basal, channeled, narrowly linear. Scape 1–2 ft. high, bracts taper-pointed, pedicels almost 1 in. long. Umbel rarely bearing bulblets. Flowers pink, rose color, or white; segments of the perianth thin. In moist soil S. and W.

5. A. vineale L. FIELD GARLIC. Bulb mostly solitary. Leaves cylindrical, hollow, very slender. Scape slender, sheathed below the middle by the bases of the leaves. Umbels often crowded with bulblets. A troublesome weed in moist meadows and fields eastward, giving milk a strong flavor of onions or garlic. Naturalized from Europe.

VII. NOTHOSCORDUM Kunth

Scape-bearing herbs resembling *Allium*, but with no odor of onions. Flowers yellow or yellowish-green, in a loose, erect umbel, with 2 bracts.

1. N. bivalve Britton. Bulb small, often with little bulbs at its base. Leaves narrowly linear. Scape not exceeding 1 ft. high, the umbel 2-bracted, pedicels thread-like, at length 1–2 in. long. Flowers $\frac{1}{2}$ in. long or less, the perianth segments narrowly oblong, thin. On prairies and in open woods.

VIII. HEMEROCALLIS L.

Perennial, from a fascicle of fleshy roots. Stem erect, branched, smooth. Leaves mostly basal and linear. Flowers on branching scapes, large, yellow or orange, solitary or corymbed. Perianth funnelform, with a spreading limb much longer than the tube. Stamens 6, inserted in the top of the tube, shorter than the lobes, curved upward. Ovary 3-celled, many-ovuled; style longer than the stamens, curved upward; stigma knobbed. Fruit a 3-celled, 3-angled capsule.*

1. **H. fulva** L. DAY LILY. Scapes stout, branched above, with a few bract-like leaves, smooth, 3–5 ft. high. Leaves very long, strap-shaped, acute, channeled. Flowers short-pediceled, tawny-yellow; perianth lobes oblong, netted-veined, lasting only one day. Introduced from Asia and common in old gardens.*

IX. LILIUM L.

Perennial, from scaly bulbs; stem erect, leafy, usually tall and slender. Leaves sessile, scattered or whorled. Flowers large, erect or drooping. Perianth corolla-like, deciduous; segments 6, spreading or recurved above, sessile or clawed, each with a nectar-bearing groove near the base. Stamens 6, elongated; anthers linear, versatile. Ovary 3-celled, many-ovuled; style long and slender; stigma 3-lobed. Fruit a 3-celled, dehiscent, many-seeded capsule.

1. **L. longiflorum** Thunb. LONG-FLOWERED WHITE LILY. Stem 1–3 ft. high. Leaves thick, lanceolate, scattered. Flower single, pure white, funnel-shaped, 5–6 in. long. Var. **eximium,** the Easter lily, bears several very showy and sweet-scented flowers. Cultivated from China and Japan.

2. **L. philadelphicum** L. WILD RED LILY. Stem 2–3 ft. high. Leaves linear-lanceolate, the upper ones generally whorled. Flower usually solitary (sometimes 2 or 3), erect, reddish-orange, with tawny or purplish spots inside. Sepals with claws. Dry or sandy ground, borders of thickets, etc.

Var. **andinum** Ker. WESTERN RED LILY. Stem rather slender. Leaves linear, all alternate or the upper ones whorled. Flowers 1–3, erect. Segments of the perianth red, orange, or yellow, spotted beneath, the claw shorter than the blade. In dry soil W.

3. **L. canadense** L. WILD YELLOW LILY, MEADOW LILY. Stem 2–5 ft. high. Leaves lanceolate, 3-nerved, the margins and nerves roughish with short hairs, whorled. Flowers usually 3, sometimes more numerous, all nodding, on peduncles 3–6 in. long, yellow or orange, with dark purple or brown spots inside. Sepals without claws, recurved. Moist meadows and borders of woods.

X. FRITILLARIA L.

Leafy-stemmed perennials, from scaly or coated bulbs. Flowers single or several, nodding. Perianth bell-shaped, a nectar-bearing spot above the base of each division. Stamens as long as the petals.

1. **F. Meleagris** L. GUINEA-HEN FLOWER. Stem 1 ft. high. Leaves linear, alternate, channeled. Flower usually single, large, purplish, checkered with blue and purple or yellow. Cultivated from Europe.

2. **F. imperialis** L. CROWN IMPERIAL. Stem 3–4 ft. high. Leaves abundant in whorls about the middle or lower part of the stem, lanceolate or lance-oblong. Flowers several, large, yellow or red, in an umbel-like cluster beneath the terminal crown of leaves. Cultivated from Europe.

XI. ERYTHRONIUM L.

Nearly stemless herbs, arising from rather deeply buried bulbs. Leaves 2, long and smooth, with underground petioles. Scape arising from between the bases of the leaves. Flower commonly single, nodding.

1. **E. americanum** Ker. YELLOW ADDER'S-TONGUE. Leaves mottled. Flowers handsome. Perianth light yellow. Style club-shaped; stigmas united.

2. **E. albidum** Nutt. WHITE DOGTOOTH VIOLET. Leaves not much mottled. Perianth bluish-white. Stigmas 3, short and spreading.

XII. TULIPA L.

Herbs appearing stemless, from coated bulbs. Leaves sessile. Scape simple. Flower solitary, erect. Perianth bell-shaped. Stamens short, awl-shaped, with broadly linear anthers. Style short; stigma thick, 3-lobed; ovary and pod triangular.

1. **T. Gesneriana** L. COMMON TULIP. Leaves 3–6, ovate-lanceolate, close to the ground. Flower large, on a smooth peduncle, color red, yellow, white, or variegated. Cultivated from Asia Minor. Many garden varieties exist.

XIII. SCILLA L.

Perennial herbs, appearing stemless, from coated bulbs. Leaves linear. Flowers racemed on a scape, generally blue. Divisions of the perianth 1-nerved, parted almost to the base. Filaments 6, often broad at the base. Style slender, with a knob-like stigma. Ovary 3-angled, 3-celled.

1. **S. sibirica** Andr. SIBERIAN SQUILL. Scapes 3–8 in. high, several from each bulb, 2–3-flowered. Leaves 2–4, narrowly strap-shaped. Flowers intense blue, short-peduncled, often nodding. Cultivated from Russia and Siberia.

XIV. CAMASSIA Lindl. (QUAMASIA)

Herbs appearing stemless, from coated bulbs. Leaves linear. Flowers racemed on a scape. Perianth of 6 blue or purple spreading sepals. Stamens with thread-like filaments, slightly perigynous. Style thread-like, ending in a knobbed stigma. Capsule 3-angled, 3-celled, several-seeded.

1. **C. esculenta** Robinson. WILD HYACINTH. Leaves keeled, weak, shorter than the scape. Flowers in a long-bracted raceme, pale blue. River bottoms and other damp, rich soil.

XV. ORNITHOGALUM L.

Herbs appearing stemless, from coated bulbs. Leaves linear, fleshy. Scape erect. Flowers in corymbs or racemes, bracted. Perianth segments 6, white, nerved, persistent. Stamens 6, hypogynous, slender; filaments flattened. Ovary sessile, 3-celled, few-ovuled. Fruit a roundish, 3-angled capsule, seeds black.*

1. **O. umbellatum** L. STAR OF BETHLEHEM. Bulb ovoid, membranous-coated. Leaves numerous, linear, fleshy; mid-vein nearly white, as long as the scape. Scape slender, 6–12 in. high. Flowers opening in sunshine, long-pediceled. Bracts linear-lanceolate, about as long as the pedicels. Perianth segments oblong-lanceolate, white with a green stripe on the back, twice the length of the stamens. Introduced from Europe; very common about old gardens.*

XVI. HYACINTHUS L.

Herbs appearing stemless, from coated bulbs. Leaves linear, fleshy. Flowers in an erect spike, pediceled, bracted. Perianth tubular below, lobed and spreading above. Stamens short, included. Style short; stigma knobbed; ovary 3-celled, many-ovuled.*

1. **H. orientalis** L. HYACINTH. Leaves lance-linear, thick and fleshy, smooth. Scape erect, many-flowered. Segments united about half their length, white, blue, or red. Filaments very short. Ovary rarely maturing seed. Common in cultivation.*

XVII. YUCCA L.

Plants with woody and leafy stems. Leaves numerous, rigid, spine-pointed, persistent. Flowers in large terminal racemes

or panicles, bracted, nodding. Perianth bell-shaped; segments 6, nearly alike, deciduous. Stamens 6; filaments thickened above, often papillose; anthers small. Ovary sessile, 3-celled or becoming 6-celled, 3-angled, many-ovuled. Fruit an oblong, 3-angled, many-seeded, dehiscent capsule, or fleshy and indehiscent.*

1. **Y. glauca** Nutt. Bear Grass, Soap Weed. Stem very short. Leaves basal, long, straight and slender, stiff, sharp-pointed, the margins white and with a few thread-like filaments, $\frac{1}{4}$–$\frac{1}{2}$ in. wide. Flowers racemed, greenish-white, globose or oblong, bell-shaped. Style green; capsule large, oblong, six-sided. Dry soil W.

2. **Y. filamentosa** L. Spanish Dagger. Stem stout, 4–12 in. high. Leaves linear or linear-lanceolate, slender-pointed, narrowed above the spreading and clasping base, spreading or recurved, smooth, with loose, thread-like filaments on the margins. Panicle elongated, with bract-like leaves on the scape, widely branched, downy-hairy above, 3–6 ft. high. Perianth white, bell-shaped, 2 in. wide. Capsule oblong, angles rounded, sides furrowed, at length 3-valved and dehiscent. In sandy soil, and often cultivated for ornament.*

XVIII. ASPARAGUS L.

Stem from fleshy, fibrous roots, erect, branched; branches slender, with thread-like branchlets in the axils of scales which take the place of leaves. Flowers small, solitary or racemed. Perianth 6-parted; segments distinct or slightly united. Stamens 6, perigynous; filaments thread-like. Ovary 3-celled, 6-ovuled; style short, slender; stigmas 3, recurved. Fruit a berry.*

1. **A. officinalis** L. Asparagus. Stem succulent and simple, with fleshy scales when young; becoming taller, more woody, and widely branched, when old. Flowers axillary, solitary, or 2 or 3 together on slender, jointed, drooping pedicels, greenish; segments linear. Berry red, few-seeded. Introduced from Europe, common in cultivation, and often escaped.*

XIX. SMILACINA Desf. (VAGNERA)

Perennial, simple-stemmed herbs, with rootstocks. Leaves usually sessile, nerved, alternate. Flowers white, in a terminal raceme. Perianth spreading, 6-parted. Stamens 6, somewhat perigynous; filaments slender; anthers short, facing inward.

Ovary 3-celled, 6-ovuled; style short and stout, with a somewhat 3-lobed stigma. Fruit a 1–2-seeded berry.

1. **S. racemosa** Desf. FALSE SPIKENARD. A showy plant with curved stem 1–3 ft. high, downy throughout. Leaves abundant, oval or ovate-lanceolate, taper-pointed. Flowers small, in a compound raceme. Berries pale red, speckled with dark red or purple. Moist thickets.

2. **S. stellata** Desf. Plant 1 ft. or less in height, nearly smooth. Leaves broadly lanceolate, acute, clasping. Flowers few, larger than in No. 1, in a simple raceme. Berries very dark red. Along river banks.

XX. MAIANTHEMUM Wiggers. (UNIFOLIUM)

Stem low. Leaves 2–3, lanceolate or ovate, with a heart-shaped base. Flowers small, white, solitary or in a simple raceme. Perianth 4-parted. Stamens 4. Ovary 2-celled; stigma 2-lobed.

1. **M. canadense** Desf. TWO-LEAVED SOLOMON'S SEAL, WILD LILY OF THE VALLEY. Plant 3–6 in. high. Leaves very short-petioled. Fruit a globular or ovoid berry, whitish, with brownish-red blotches. Woods and shaded banks N.

XXI. STREPTOPUS Michx.

Herbs with forking stems from a creeping rootstock. Leaves clasping. Flowers small, borne singly or in pairs on peduncles which arise above the leaf axils and which are sharply bent or twisted near the middle. Anthers arrow-shaped. Ovary 3-celled, ripening into a red, many-seeded berry.

1. **S. amplexifolius** DC. LIVER BERRY. Stem smooth, 2 ft. or more high. Leaves smooth-margined. Flowers greenish-white. Damp woods.

2. **S. roseus** Michx. LIVER BERRY, JACOB'S LADDER. Branches with a few bristly hairs. Lower leaves margined with fine bristles. Flowers reddish or purplish. Cold, damp woods N.

XXII. POLYGONATUM Hill. (SALOMONIA)

Rootstock creeping, jointed, scarred. Stems simple, erect, scaly below, leafy above. Leaves alternate, oval or oblong. Flowers on axillary, 1–4-flowered, drooping, jointed peduncles.

Perianth tubular, 6-cleft. Stamens 6, included, inserted about the middle of the tube; anthers arrow-shaped. Ovary 3-celled, many-ovuled; style slender; stigmas knobbed or 3-lobed. Fruit a few-seeded berry.*

1. **P. biflorum** Ell. HAIRY SOLOMON'S SEAL. Stem simple, erect, arched, nearly naked below, 1–2 ft. high. Leaves 2-ranked, sessile or clasping, 3–7-nerved, smooth above, pale and downy beneath. Peduncles short, 1–4, often 2-flowered. Perianth greenish, 1–2 in. long. Filaments thread-shaped, roughened. Berry dark blue. Shady banks.*

2. **P. commutatum** Dietrich. SMOOTH SOLOMON'S SEAL. Stem simple, stout, curving above, 3–8 ft. high. Leaves lanceolate to ovate, many-nerved, partly clasping, smooth on both sides. Peduncles nearly half as long as the leaves, 2–6-flowered. Perianth greenish-yellow, $\frac{3}{4}$ in. long. Filaments smooth. Berry blue, $\frac{1}{2}$ in. in diameter. In rocky woods and along streams.*

XXIII. CONVALLARIA L.

Low, smooth, apparently stemless, perennial herbs. Leaves 2, oblong, with long petioles, from a slender, creeping rootstock. Scape slender, angled, inclosed at the base by the leafstalks. Flowers racemed, white, drooping. Perianth bell-shaped, with recurved lobes. Stamens borne on the base of the perianth. Ovary 3-celled, ripening into a few-seeded red berry.

1. **C. majalis** L. LILY OF THE VALLEY. A familiar garden flower, cultivated from Europe, and also found wild in mountain woods from Virginia to Georgia.

XXIV. TRILLIUM L.

Low herbs, with the stem springing from a short rootstock. Leaves 3, large, netted-veined, in a whorl. Flower large, terminal. Perianth of 6 parts, the 3 sepals unlike the 3 petals in color and in texture. Stamens 6, with the linear anthers usually opening inward, longer than the filaments. Stigmas 3, sessile, spreading at the tips; ovary 3- or 6-angled, 3-celled, many-seeded. Fruit a roundish, many-seeded purple berry.

1. **T. sessile** L. Rootstock erect or ascending, corm-like. Stem slender, 1–8 in. high. Leaves broadly oval, obtuse or acute at the apex, rounded and sessile at the base, 3–5-nerved, smooth, bright

green, not mottled. Flowers sessile; sepals lanceolate, $\frac{2}{3}$–1 in. long; petals purple, elliptical, about the length of the sepals. Stamens half the length of the petals. Styles elongated, straight. In rich woods.*

2. T. erectum L. SQUAWROOT, BENJAMIN. Rootstock rather upright, large and stout. Leaves broadly diamond-shaped, tapering to a short point. Pedicel 1–3 in. long, not quite erect. Petals ovate to lanceolate, much broader than the sepals, of a rich brownish-purple or sometimes white or pale. Stigmas distinct, stout, and spreading. The disagreeable scent of the flower has given rise to several absurd popular names for it. In rich woods.

3. T. grandiflorum Salisb. LARGE-FLOWERED WAKE-ROBIN. Rootstock horizontal, stem slender, 12–18 in. high. Leaves rhombic-ovate, taper-pointed at the apex, rounded and sessile or slightly peduncled at the base, smooth and with a bloom, 5–7-nerved, bright green. Peduncle longer than the erect or slightly declined flower. Sepals lanceolate-acute, 1–1½ in. long. Petals white, fading to pink, longer than the sepals. Stamens less than half the length of the petals. Style short; stigmas recurved. Fruit a black, roundish berry. In rich woods.*

4. T. cernuum L. NODDING TRILLIUM. Stem 8–20 in. high. Leaves broadly rhombic or rhombic-ovate, 2–4 in. wide, taper-pointed, sessile or nearly so. Peduncle recurved beneath the leaves. Petals white or pink, wavy, somewhat recurved, as long as the sepals or a little longer. Stamens with filaments about equaling the anthers. Stigmas stout, recurved. Rich moist woods.

5. T. nivale Riddell. DWARF WHITE TRILLIUM. Stem 2–4 in. high. Leaves petioled, oval to ovate. Flower white, erect. Petals ½–1¼ in. long, ovate-spatulate. Rich, damp woods, blooming with the very earliest spring flowers.

6. T. undulatum Willd. PAINTED TRILLIUM. Stem 8–12 in. high. Rootstock oblique to the rest of the stem, rather small; roots long and fibrous. Leaves ovate, taper-pointed. Petals white, penciled at the base, with purple stripes, lance-ovate, somewhat recurved, wavy. Cold woods, especially N.

XXV. SMILAX L.

Mostly woody vines, usually with prickly stems, climbing by tendrils. Rootstock often large and tuberous. Leaves alternate, prominently nerved, netted-veined, petioled; stipules replaced by persistent tendrils. Flowers regular, diœcious, small, greenish, in axillary umbels. Perianth bell-shaped, segments 6. Stamens 6, distinct. Ovary 3-celled, 3–6-ovuled; stigmas 1–3, sessile or nearly so. Fruit a 1–6-seeded globose berry.

1. **S. herbacea** L. Carrion Flower. Stem herbaceous, erect, simple or branched, not prickly, 1–3 ft. high. Leaves few, ovate, acute, and mucronate at the apex, somewhat heart-shaped at the base, 5–7-nerved, thin, smooth above, downy below, the upper sometimes whorled and the lower bract-like; petiole short. Peduncles as long as the leaves, growing from below the petiole. Umbel many-flowered, flowers carrion-scented. Berry blue-black, 2–4-seeded. Dry, fertile soil.*

2. **S. Walteri** Pursh. Green-Brier. Stem low, with few prickles, 2–5 ft. long; branches slightly 4-angled, unarmed. Leaves oblong-lanceolate to oval, obtuse or acute at the apex, rounded or cordate at the base, 5-ribbed, smooth. Peduncles flattened, about as long as the petioles and pedicels. Berry bright red, ripening the first year. Wet pine barrens.*

3. **S. rotundifolia** L. Green-Brier, Cat-Brier, Dog-Brier, Horse-Brier, Wait-a-Bit. Stem green, strong; branchlets, and sometimes the branches, 4-angled, armed with stout hooked prickles. Leaves ovate or round-ovate, with a slightly heart-shaped base and an abruptly pointed tip. Berries black, with a bloom. Thickets, the commonest species N. E.

4. **S. glauca** Walt. Green-Brier. Stem cylindrical, slender, with scattered prickles, branches angled and usually without prickles. Leaves ovate or subcordate, pointed at the apex, mostly 5-nerved, smooth, white beneath, with a bloom, margin entire. Peduncle flattened, 2–3 times as long as the petiole, few-flowered. Berry black, 3-seeded. Margin of swamps.*

5. **S. Bona-nox** L. Bamboo Vine. Stem stout, cylindrical or slightly angled, scurfy when young, armed with numerous stout prickles. Branches 4-angled, usually unarmed. Leaves triangular, ovate, or often halberd-shaped, 5–7-ribbed, smooth on both sides and often discolored; margins usually fringed with fine prickles. Peduncles twice as long as the petioles, flattened. Umbels many-flowered; pedicels short. Berries 8–20 in a cluster, black, 1-seeded. In swamps and thickets.*

11. AMARYLLIDACEÆ. Amaryllis Family

Mostly smooth perennial herbs, from bulbs. Leaves basal, with no distinction between petiole and blade. Flowers borne on a scape, nearly or quite actinomorphic. Stamens 6. Style 1. Limb of the 6-parted, corolla-like perianth epigynous. Ovary 3-celled. Capsule 3-celled, several–many-seeded.

I. NARCISSUS L.

Scapes with 1–several flowers from a thin, dry spathe. Flowers with a cup-shaped or other crown on the throat of the perianth; tube of the perianth somewhat cylindrical, the 6 divisions of the limb widely spreading. Stamens 6, inserted in the tube.

1. **N. Psuedo-Narcissus** L. DAFFODIL, DAFFY, EASTER FLOWER. Scape short, bearing 1 large yellow flower; tube of perianth short and wide, crown with a crimped margin. Cultivated from Europe.

2. **N. Tazetta** L., var. **orientalis.** CHINESE SACRED LILY. Bulb large, often with many smaller ones attached to its base. Scape 1 ft. or more high. Flowers several, umbeled, fragrant. Perianth white or nearly so, the crown rather spreading, finely scalloped, yellow or orange. Cultivated from China.

3. **N. poeticus** L. POET'S NARCISSUS. Scape 1-flowered. Perianth pure white, the crown very narrow, edged with pink. Cultivated from S. Europe.

II. ZEPHYRANTHES Herb. (ATAMOSCO)

Stemless, from a coated bulb. Leaves linear, fleshy. Scape erect, 1–few-flowered. Flowers large, erect, or declined, subtended by a 1–2-leaved spathe. Perianth 6-parted, naked in the throat; tube short, segments petal-like, spreading. Stamens free, anthers versatile. Ovary 3-celled, many-ovuled; style elongated, declined; stigma 3-cleft. Fruit a many-seeded, 3-valved capsule; seeds black, compressed, or angled.*

1. **Z. Atamasco** Herb. ATAMASCO LILY. Bulbs about 1 in. in diameter. Leaves narrow, concave above, smooth, usually longer than the scape. Scape 6–12 in. high, 1-flowered. Spathe 1-leaved, 2-cleft. Flowers 2–3 in. long, white, tinged with pink or purple, bell-shaped, short-peduncled. Stamens longer than the tube, shorter than the style. Capsule depressed-globose, seeds angled. In rich, damp soil, often cultivated.*

III. HYPOXIS L.

Small, apparently stemless herbs. Leaves grass-like, hairy, from a solid bulb. Scapes thread-like, few-flowered. Perianth 6-parted, wheel-shaped, the 3 outer divisions greenish on the outside, the whole perianth withering on the pod. Seeds numerous.

1. **H. hirsuta** Coville. STAR GRASS. Leaves longer than the scape, both sparsely set with long, soft hairs. Scape 3–8 in. high. Flowers 1–4, about ½ in. across, yellow. Common in meadows and dry woods.

12. IRIDACEÆ. IRIS FAMILY

Perennial herbs from bulbs, corms, or rootstocks. Leaves 2-ranked, equitant. Flowers bisexual, often actinomorphic, each subtended by two bracts. Perianth 6-parted, the segments epigynous in 2 series of 3 each, equal, or the inner ones smaller. Stamens 3, distinct or united, opposite the outer segments. Ovary forming a 3-celled, 3-angled, 3-valved, many-seeded, dehiscent capsule.*

I. CROCUS L.

Leaves springing from the corm. Flowers sessile on the corm. Tube of the perianth very long and slender, its divisions all alike or nearly so. Stigmas 3-cleft.

1. **C. vernus** All. SPRING CROCUS. Leaves linear. Stigmas short. Flowers white, blue, or purple. Our earliest garden flower. Cultivated from Europe.

II. IRIS L.

Rootstock thick, creeping, branching, horizontal, sometimes tuberous. Stems erect, simple or branched. Leaves linear or sword-shaped. Flowers showy, the outer perianth segments spreading or recurved, often bearded within, the inner segments usually smaller and erect. Stamens inserted in the base of the outer segments. Style deeply 3-parted (Fig. 8), the divisions broad and petal-like, covering the stamens. Fruit an oblong or oval, 3- or 6-angled, many-seeded capsule (Fig. 9).*

1. **I. versicolor** L. LARGE BLUE FLAG. Rootstock thick, horizontal. Stem cylindrical, smooth, simple or branched, leafy, 2–3 ft. high. Leaves linear, sword-shaped, finely nerved, with a bloom, the lower 1½–2 ft. long, the upper shorter. Bracts longer than the pedicels. Flowers terminal, single or few together, blue variegated with white, yellow, and purple; perianth segments not bearded, the inner ones smaller. Ovary 3-angled, longer than the inflated perianth tube. Capsule oblong, slightly lobed; seeds 2 rows in each cell. In wet places.*

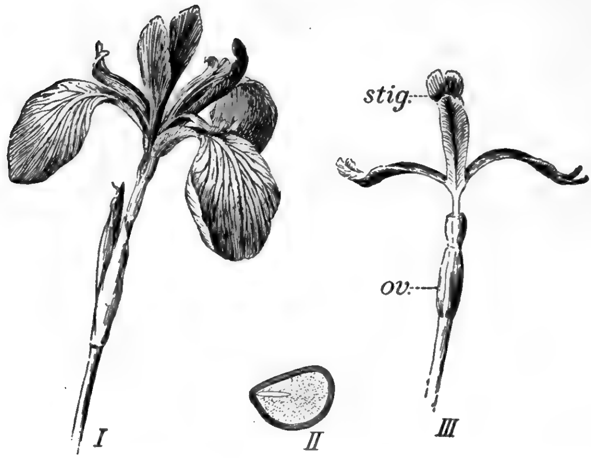


Fig. 8. Iris

I, flower. II, seed, longitudinal section. III, flower with outer segments of perianth removed: *stig.*, stigma, *ov.*, ovary

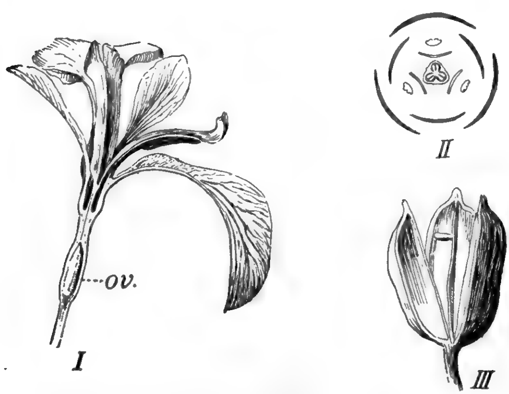


Fig. 9. Iris

I, flower, longitudinal section: *ov.*, ovary. II, diagram showing stigmas opposite the stamens; III, capsule, splitting between the partitions

2. I. prismatica Pursh. SLENDER BLUE FLAG. Rootstock rather slender, with tuber-like thickened portions. Stem slender, cylindrical, usually unbranched, 1–3 ft. high. Leaves 2–3 in number, narrowly linear, $\frac{1}{6}$–$\frac{1}{4}$ in. wide. Flowers slender-peduncled, solitary or in twos, blue with yellow veins, the perianth tube beardless and crestless. Ovary 3-angled; capsule sharply 3-angled. Marshy soil near the coast.

3. I. fulva Ker. YELLOW FLAG. Rootstock fleshy. Stem simple or branched, grooved, 1-angled below, bearing 2–3 leaves, 2–3 ft. high. Leaves linear, sword-shaped, with a bloom, shorter than the stem; bracts small. Pedicels short, flowers axillary and terminal, dull yellow or reddish-brown, variegated with blue and green, perianth segments not bearded. Style branches but little exceeding the stamens; ovary about as long as the inflated perianth tube; capsule ovate, 6-angled. Swamps and wet places.*

4. I. germanica L. FLEUR-DE-LIS. Rootstock thick, matted. Stem stout, branched, leafy, 2–3 ft. high. Leaves strap-shaped, acute, erect, shorter than the stem; bracts scarious. Flowers sessile, large and showy, blue variegated with white and yellow, sometimes nearly all white; outer segments large, recurved, bearded, the inner narrower, erect, or arched inward. Introduced from Europe; common in gardens and naturalized in many places.*

III. SISYRHINCHIUM L.

Small, grass-like perennials. Stems erect, flattened, or winged. Roots fibrous. Leaves linear or lanceolate. Flowers small, blue, quickly withering, in terminal 2-bracted umbels. Perianth corolla-like, of 6 bristle-pointed segments; tube nearly or wholly lacking. Stamens 3, completely monadelphous. Stigmas 3, thread-like. Fruit a nearly globular, 3-angled capsule. Species too difficult for the beginner; all commonly known as Blue-Eyed Grass.

13. ORCHIDACEÆ. ORCHIS FAMILY

Perennial herbs with simple stems, often arising from bulbs or tubers. Leaves simple, usually alternate and entire. Flowers bisexual, generally showy, epigynous, zygomorphic, and often of extraordinary shapes. Perianth of 6 divisions. Stamens 1 or 2, united with the pistil; pollen of comparatively

few grains, held together in masses by cobweb-like threads. Ovary 1-celled, containing many (sometimes more than a million) very minute ovules.

The family is a difficult one, and most of the genera are so rare that specimens should not be collected in large numbers for class study. Two of the most familiar genera are *Cypripedium*, or Lady's Slipper, and *Spiranthes*, or Lady's Tresses. Many of the genera are tropical air plants.

SUBCLASS II. DICOTYLEDONOUS PLANTS

Stems composed of bark, wood, and pith; the fibro-vascular bundles in rings; in woody stems which live over from year to year, the wood generally in annual rings, traversed at right angles by medullary rays. Leaves netted-veined. Parts of the flower usually in fours or fives. Cotyledons 2 (rarely none).

14. SALICACEÆ. Willow Family

Diœcious trees or shrubs, with flowers in catkins, destitute of floral envelopes. Fruit a 1-celled pod, with numerous seeds, provided with rather long and silky down, by means of which they are transported by the wind.

I. SALIX L.

Shrubs or trees, branches usually very slender. Buds with single scales. Leaves usually long and narrow; stipules sometimes leaf-like or often small and soon deciduous. Bracts of the catkins entire. Staminate catkins erect or drooping (Fig. 10); staminate flowers with 2–10, mostly 2, distinct or united stamens. Pistillate catkins usually erect (Fig. 10); flowers with a small gland on the inner side of the bract; stigmas short, 2-lobed. Capsule 2-valved.*

[Thirty or more species of willow are found growing wild in the northeastern and north central states, but they are very hard, even for botanists, to identify.]

1. S. nigra Marsh. BLACK WILLOW. A small tree with very brittle branches. Leaves elliptical or narrowly lanceolate, acute at each end, serrate, short-petioled, downy when young and becoming smooth with age, 2–3 in. long; stipules persistent or deciduous. Staminate catkins 1–2 in. long; the pistillate 2–4 in. long. Stamens 3–7, distinct; filaments soft-hairy below. Capsule twice the length of the pedicel, ovate, taper-pointed, pointed by the prominent style. Along streams and borders of marshes.*

2. S. lucida Muhl. SHINING WILLOW. A large shrub or sometimes a bushy tree 20 ft. high, with smooth bark, yellowish-brown and shining on the twigs. Leaves varying from ovate to lanceolate, usually with very slender tapering points, sharply and finely serrate, firm, green, and glossy on both sides, 3–5 in. long; stipules small, oblong, usually persistent. Catkins borne on short leafy branches, the staminate ones stout, 1–1½ in. long, the pistillate ones slender, 1½–2 in. long, lengthening in fruit to 3–4 in. Stamens usually 5. Capsule narrowly ovoid or cylindrical, pointed, smooth, and shining. Banks of streams, lakes, and swamps. One of the most beautiful willows from the showiness of the staminate catkins and the large glossy leaves.

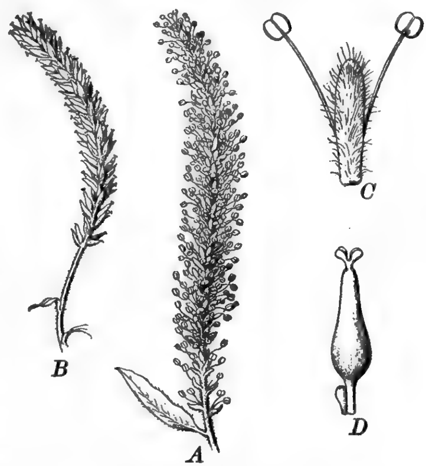


FIG. 10. White willow (*Salix alba*)

A, staminate catkin, natural size; *B*, pistillate catkin, natural size; *C*, a staminate flower, magnified; *D*, a pistillate flower, magnified. (After Cosson and De Saint-Pierre)

3. S. alba L. WHITE WILLOW, YELLOW WILLOW. A spreading tree 50–80 ft. high, with rough gray bark, yellowish-green on the twigs. Leaves lanceolate, narrowed at the base, with long tapering points, gray or silky-downy on both sides when young, the upper surface (especially in Var. *vitellina*) becoming smooth when old, 2–4 in. long; stipules ovate-lanceolate, deciduous. Catkins on short leafy branches, the pistillate ones slender, cylindrical, 1¼–3½ in. long. Stamens usually 2. Capsule ovoid, pointed. Cultivated from Europe (especially Var. *vitellina*), and

occasionally escaped from cultivation along streams. Very variable and with many hybrids.

4. S. babylonica L. Weeping Willow. A spreading tree, sometimes 60 ft. or more in height, with drooping branches. Leaves narrowly lanceolate, taper-pointed, serrate, slightly downy when young and becoming smooth with age, green above, pale beneath, often 5–7 in. long; petioles short, glandular. Catkins on short lateral branches. Stamens 2. Style almost none. Capsule sessile, smooth. Introduced and cultivated for ornament.

5. S. cordata Muhl. Heart-Leaved Willow. A shrub 4–10 ft. high, with twigs finely downy or smooth. Leaves oblong-lanceolate, taper-pointed, finely and sharply serrate, often tapering but frequently obtuse or somewhat heart-shaped at the base, finely downy when young (especially on the midrib) but smooth when old; sometimes 5 in. long; stipules usually large and conspicuous, unequal-sided, finely serrate, generally persistent. Catkins with bracts at the base, opening earlier than the leaves, the staminate ones very silky, less than 1 in. long, the fertile ones in fruit 1½–2½ in. long. Capsules narrowly ovoid, pointed. In wet soil and along streams, very variable and widely distributed.

6. S. discolor Muhl. Glaucous Willow, Pussy Willow. A low tree, sometimes 20 ft. or more in height, with light greenish-brown or reddish-brown bark. Leaves oblong-lanceolate, tapering at both ends, finely and irregularly toothed or nearly entire, on slender petioles, smooth and firm, bright green above, smooth or silvery white below, 3–5 in. long; stipules often leaf-like, unsymmetrical, usually deciduous. Staminate catkins very white and silky, oblong-cylindrical, 1 in. or more long, appearing much earlier than the leaves; pistillate catkins 1½–2½ in. or more long. Stamens 2, with long, slender filaments. Capsule cylindrical or nearly so, long-beaked. Common in wet meadows or along streams and swamps.

II. POPULUS L.

Trees with prominent scaly buds, twigs more or less angled. Leaves usually long-petioled.

Flowers borne in long, drooping catkins, which appear before the leaves; scales of the catkins irregularly cut toward the tip. Stamens 8–30 or more. Stigmas 2–4. Capsules opening early by 2–4 valves.

1. P. alba L. Silver-Leaved Poplar, White Poplar. A large tree, sometimes more than 100 ft. high, with smooth greenish-gray bark. Leaves broadly ovate, rhombic-oval or nearly orbicular, lobed

or very coarsely toothed, densely white-downy beneath. Cultivated as a shade tree and sometimes found growing spontaneously.

2. P. tremuloides Michx. AMERICAN ASPEN, QUAKING ASP. A tree 20–60 ft. high, with greenish-white bark. Leaves roundish, heart-shaped, abruptly pointed, with small regular teeth. Leafstalk long, slender, and flattened at right angles to the broad surfaces of the leaf, causing it to sway edgewise with the least perceptible breeze. Common especially N.

3. P. grandidentata Michx. LARGE-TOOTHED POPLAR. A tree 60–80 ft. high, with rather smooth gray bark. Leaves 3–5 in. long, roundish-ovate and irregularly sinuate-toothed; when young completely covered with white silky wool, which is shed as soon as the leaf matures. The petiole is somewhat flattened, but not nearly as much so as that of the preceding species. Rich woods N.

4. P. heterophylla L. SWAMP POPLAR. Branches only slightly angled. Leaves ovate, mostly obtuse at the apex, rounded or subcordate at the base, serrate with obtuse teeth, densely woolly when young, but becoming smooth with age; petioles cylindrical. Pistillate catkins smooth, erect or spreading, loosely flowered. Capsule ovoid, usually shorter than the pedicel. Common in river swamps. A large tree with soft light wood, which is often used in making cheap furniture.*

5. P. deltoides Marsh. COTTONWOOD. A large and very rapidly growing tree, 75–100 ft. or more high, often with a markedly excurrent trunk. Leaves large and broadly triangular, with crenate-serrate margins and long, tapering, acute tips; petioles long and considerably flattened. The numerous pediceled capsules are quite conspicuous when mature, and the air is filled with the downy seeds at the time when the capsules open. Common W., especially along streams, and planted as a shade tree.

15. MYRICACEÆ. BAYBERRY FAMILY

Shrubs with alternate, simple, resinous-dotted leaves; monœcious or diœcious. Flowers in short, bracted catkins; perianth none. Staminate flowers 2–10, stamens hypogynous; pistillate flowers surrounded by 2–6 scales. Ovary 1-celled; style short; stigmas 2.

I. MYRICA L.

Shrubs or small trees with the branches clustered at the end of the growth of the previous season. Leaves short-petioled, entire, lobed or toothed, the margin usually revolute,

without stipules. Perianth none. Staminate flowers in oblong or cylindrical catkins; stamens 2–10, with the filaments united below. Pistillate flowers surrounded by a cup of 2–6 scales; ovary solitary, becoming a 1-celled, roundish drupe or nut, often covered with waxy grains. Whole plant usually fragrant.*

1. M. carolinensis Mill. WAXBERRY, BAYBERRY. A spreading shrub or small tree; young branches downy. Leaves lanceolate or oblong-lanceolate, entire or sometimes serrate near the mostly obtuse apex, smooth or downy on the veins beneath, tapering into a short petiole. Flowers mostly diœcious. Staminate catkins numerous, stamens 4. Pistillate catkins small, bracts slightly 3-lobed, scales of the ovary 4, fringed with hairs; stigmas 2. Fruit very abundant, incrusted with white wax, $\frac{1}{8}$–$\frac{1}{6}$ in. in diameter, sometimes persistent for 2 or 3 years. Common on wet soils, especially near the coast.*

2. M. asplenifolia L. SWEET FERN. A shrub 2 ft. or less in height, with brown twigs. Leaves fern-like, linear-lanceolate, 20–30-lobed, 3–5 in. long and very fragrant. Often monœcious. Staminate catkins cylindrical; pistillate catkins globular. Ovary surrounded by 8 long, linear, awl-shaped, hairy and glandular scales which encircle the ripened fruit. Nut nearly ovoid, smooth, small, but eaten by children.

16. JUGLANDACEÆ. WALNUT FAMILY

Trees with alternate, odd-pinnate leaves without stipules. Flowers monœcious, the staminate in long and drooping catkins; stamens few or many; calyx 2–6-parted. Fertile flowers solitary or in small clusters; calyx 3–5-lobed, minute petals sometimes present. Ovary inferior, 1-celled or incompletely 2–4-celled. Fruit (strictly speaking a drupe) with a dry husk inclosing a bony nut.*

I. JUGLANS L.

Staminate catkins cylindrical, solitary, borne on wood of the previous year; stamens numerous, filaments short; calyx 4–6-parted. Pistillate flowers single or a few together on a short peduncle at the base of the growth of the season. Calyx 4-parted. Petals 4, minute, epigynous. Styles 2, short, plumose. Fruit large, roundish or oval, husk fibrous-fleshy, becoming dry, indehiscent; nut bony, very rough.*

1. J. cinerea L. BUTTERNUT. Leaflets 15–19, ovate-lanceolate, taper-pointed at the apex, rounded or slightly unsymmetrical at the base, serrate, downy beneath; petioles, branchlets, and fruit clothed with short, sticky hairs. Fruit often somewhat in clusters, oblong, large. More common northward. Wood less valuable and nut less oily than the black walnut. The English walnut (*J. regia*) is occasionally seen in cultivation. It has 7–11 leaflets and a nearly smooth nut.*

2. J. nigra L. BLACK WALNUT. Leaflets 13–21, ovate-lanceolate, serrate, taper-pointed, somewhat cordate or oblique at the base, nearly smooth above, downy beneath; petioles minutely downy. Fruit usually single, roundish, about 2 in. in diameter. On rich soil, rare near the coast. One of the most valuable of our native trees, the wood being very durable and highly prized for cabinet work.*

II. CARYA Nutt. (HICORIA)

Leaflets serrate. Staminate catkins usually in threes on a common peduncle, or sometimes sessile at the base of the growth of the season; calyx 2–3-parted; stamens 3–10, filaments short. Pistillate flowers 2–5 in terminal clusters; calyx 4-parted; petals none; styles 2 or 4, fringed. Fruit somewhat globular, husk separating more or less completely into 4 valves; nut smooth or angled.*

1. C. illinoensis K. Koch. PECAN. A large tree with rough gray bark, young twigs and leaves downy, nearly smooth when mature. Leaflets 11–15, oblong-lanceolate, acuminate, serrate, scythe-shaped. Staminate catkins nearly sessile, 5–6 in. long. Husk of fruit thin; nut oval or oblong, thin-shelled. River bottoms. Rarely native east of the Mississippi River, but widely planted for its fruit.*

2. C. ovata K. Koch. SHELLBARK HICKORY. A large tree with bark scaling off in long plates; young twigs and leaves downy, becoming smooth with age. Leaflets 5, the lower ones oblong-lanceolate, the upper one longer and obovate, taper-pointed at the apex, narrowed to the sessile base. Inner bud scales becoming large and conspicuous. Staminate catkins in threes. Fruit globose, husk thick, splitting into four sections; nut white, compressed, 4-angled, pointed, thin-shelled. On rich soil; more common N. Wood strong and elastic, but not durable when exposed.*

3. C. laciniosa Loud. BIG SHELLBARK, KING NUT, BULL NUT. A tree 70–90 ft. high, with shaggy bark. Leaflets 7 or 9, the terminal one nearly sessile. Fruit large, ovoid or nearly so, 4-grooved toward the outer end, the husk very thick, nut pointed at each end, 1½–2 in.

long, thick-shelled, with a very sweet kernel. Wood hard and heavy. Common in rich, damp soil W.

4. C. alba K. Koch. MOCKER NUT, WHITE-HEART HICKORY. A large tree 70–100 ft. high, with close, rough bark; catkins, twigs, and under surfaces of the leaves downy and resinous-scented when young. Leaflets 7–9, oblong-lanceolate or obovate-lanceolate, taper-pointed. Fruit globose or nearly so, with a very thick, hard husk; nut with 4 ridges toward the apex, very thick-shelled, with a small, sweet kernel. On rich hillsides. Wood much like that of *C. ovata*.

5. C. cordiformis K. Koch. PIGNUT, SWAMP HICKORY. A medium-sized tree, with rather smooth bark. Leaflets 7–11, lanceolate or oblong-lanceolate. Fruit not large, husk thin; nut globular, with a short point, very thin-shelled; kernel extremely bitter. Moist soil, common in the Middle States.

17. BETULACEÆ. BIRCH FAMILY

Trees or shrubs with alternate, simple, petioled leaves, with usually deciduous stipules. Flowers monœcious in cylindrical or subglobose catkins. Staminate catkins drooping; flowers 1–3 in the axil of each bract; calyx none or membranous and 2–4-parted; stamens 2–10, distinct. Pistillate catkins drooping, spreading, or erect and spike-like; flowers with or without a calyx; ovary solitary, 1–2-celled; ovules 1–2 in each cell. Fruit a 1-celled nut or a key.*

I. CORYLUS L.

Shrubs with prominently veined, cut-toothed leaves, which are folded lengthwise in the bud. Flowers expanding before the leaves. Staminate flowers in slender, drooping catkins; stamens 8, anthers 1-celled. Fertile flowers several in a cluster or in very short catkins at the ends of the twigs of the season; ovary incompletely 2-celled; style short; stigmas 2; bractlets 2, becoming enlarged and inclosing the single bony nut at maturity.*

1. C. americana Walt. HAZELNUT. A shrub 2–5 ft. high; young twigs and petioles covered with brownish, stiff hairs. Leaves not very thin, round-cordate, acute or slightly taper-pointed, irregularly toothed, nearly smooth above, downy below. Involucre longer than

the nut and partially inclosing it, glandular-hairy. Nut subglobose, pointed, edible. On rich soil, borders of meadows and fields, and in oak openings.

2. C. rostrata Ait. Beaked Hazelnut. A shrub 4–8 ft. high. Young twigs near ends smooth. Leaves thin, little if at all heart-shaped, doubly serrate or incised, taper-pointed, stipules linear-lanceolate. Involucre completely covering the nut and prolonged into a beak beyond it. Common N. [The latter species is not nearly as widely distributed as the former; they cannot be readily distinguished from each other until the fruit is somewhat mature. The principal points of difference discernible before the fruit is nearly mature are the hairy twigs of No. 1 and the smooth ones of No. 2, and the fact that No. 1 has buds rounded at the apex and more slender and longer staminate catkins, while No. 2 has buds acute at the apex and thicker and shorter staminate catkins.]

II. OSTRYA Scop.

Small trees with gray bark and very hard wood. Leaves open and concave in the bud and somewhat plaited on the veins. Staminate flowers on slender, drooping catkins, sessile at the end of the growth of the previous season; stamens 3–12, subtended by a bract; filaments forked; anthers hairy. Pistillate flowers surrounded by a tubular bractlet, which becomes large and bladder-like at maturity. Fruit a small, pointed, smooth nut; mature catkins hop-like.*

1. O. virginiana K. Koch. A small tree with brownish, furrowed bark. Leaves ovate, acute, doubly serrate, often inequilateral at the base, short-petioled. Staminate and fertile catkins 2–3 in. long. In rich woods. Often known as "ironwood" and "leverwood." *

III. CARPINUS L.

Trees with thin, straight-veined leaves, which are folded in the bud. Flowers appearing before the leaves. Staminate flowers in slender, drooping catkins, sessile at the end of the growth of the previous season; stamens 3–12, subtended by a bract; filaments forked; anthers hairy. Pistillate catkins spike-like, each pair of flowers subtended by a deciduous bract, and each flower by a persistent bractlet, which becomes large and leaf-like in fruit; ovary 2-celled, 2-ovuled; stigmas 2, thread-like. Fruit a small, angular nut.*

1. **C. caroliniana** Walt. HORNBEAM. A small tree with smooth and close gray bark; twigs slender. Leaves ovate-oblong, acute or taper-pointed, sharply and doubly serrate, the straight veins terminating in the larger serrations; downy when young and soon becoming smooth. Staminate catkins 1–1½ in. long. Pistillate catkins long-peduncled, 8–12-flowered; bractlets becoming nearly 1 in. long, cut-toothed, the middle tooth much longer than the others. In rich, moist woods. Often known as "blue beech" and "ironwood."*

IV. BETULA L.

Trees with slender, aromatic twigs, and thin, usually straight-veined leaves. Staminate catkins drooping, flowers usually 3 in the axil of each bract; stamens 4, short; anthers 1-celled. Pistillate catkins erect, flowers 2 or 3 in the axil of each bract; ovary sessile, 2-celled; styles 2; bracts 3-lobed; perianth none. Nut broadly winged.*

1. **B. lenta** L. CHERRY BIRCH. Leaves ovate or oblong-ovate, acute, heart-shaped, finely and doubly serrate, silky when young; petioles about ½ in. long. Staminate catkins clustered, 3–4 in. long. Pistillate catkins sessile, about 1 in. long; cylindrical bracts spreading, acute, smooth. River banks, especially N. A large tree, with aromatic twigs. The oil contained in the bark and twigs is distilled and used as a substitute for wintergreen.*

2. **B. lutea** Michx. f. YELLOW BIRCH. A large forest tree, sometimes 60–90 ft. high, with yellowish or silver-gray bark, which peels off in extremely thin layers. Leaves ovate or nearly so, usually taper-pointed, rounded or sometimes almost heart-shaped at the base, sharply and finely serrate, somewhat downy on the veins beneath, 3–5 in. long. Staminate catkins 3–3½ in. long; pistillate catkins about ⅔ in. long. Rich woods N., also southward in the mountains.

3. **B. nigra** L. RIVER BIRCH, RED BIRCH. A medium-sized tree with reddish-brown bark. Leaves rhombic-ovate, acute at the apex, acute or obtuse at the base, sharply and doubly serrate, white-downy below, becoming smoother with age, petioles short. Staminate catkins 2–3 in. long. Pistillate catkins 1–1½ in. long, peduncles short, bracts nearly equally 3-cleft, woolly. River banks, especially S. and W.*

4. **B. populifolia** Marsh. GRAY BIRCH. A tall shrub or slender, straggling tree, 15–30 ft. high, seldom growing erect, often several trunks springing from the ground almost in contact and slanting away from each other. Leaves triangular, with a long taper point and truncate base, unevenly twice serrate, with rather long, slender petioles, which allow the leaves to quiver like those of the aspen.

Bark scaling off in white strips and layers, but not in nearly as large sheets as that of the rarer canoe birch (*B. papyrifera*). The commonest birch of New England.

5. B. alba L. EUROPEAN WHITE BIRCH, CUT-LEAVED BIRCH. A tree 50–60 ft. high, often with drooping branches. Leaves triangular-ovate, truncate, rounded or somewhat heart-shaped at

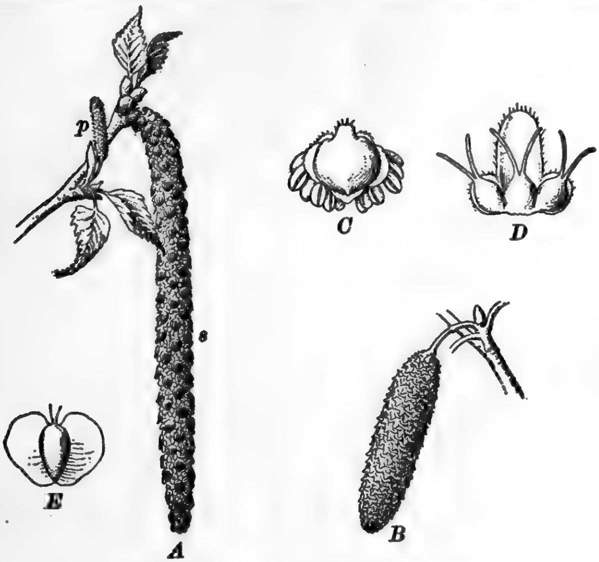


FIG. 11. Gray birch (*Betula populifolia*)

A, catkins, natural size: *s*, staminate; *p*, pistillate. *B*, cluster of ripened fruits; *C*, bract with three staminate flowers; *D*, bract with three pistillate flowers; *E*, fruit. (*B*, *C*, *D*, *E*, somewhat magnified)

the base, not strongly taper-pointed except in the cut-leaved form. Commonly cultivated from Europe. Resembles No. 4, but has whiter bark and (the weeping form) much more slender branches.

Var. papyrifera. CANOE BIRCH, PAPER BIRCH. A large tree, often 60–70 ft. high, with chalky-white papery bark, peeling off in large thin sheets. Leaves ovate, acute or taper-pointed, coarsely serrate or dentate, but entire at the base, dark green and usually without glands on the upper surface, on the lower surface light yellowish-green and nearly smooth, but with tufts of hairs in the

forks of the veins and numerous black glands, 2–3 in. long, with slender petioles. Staminate catkins 3–4 in. long; pistillate catkins $1-1\frac{1}{2}$ in. long, peduncles 2-bracted. Rich soil on hillsides, along streams, and near lakes and swamps, N. and N.E. The beautiful bark is much used by the Indians for canoes, for basket making, and for other purposes.

V. ALNUS Hill

Shrubs or small trees. Leaves petioled, serrate. Flower buds stalked, appearing the previous season; staminate catkins racemed, drooping; flowers 3–6 in the axil of each bract, subtended by 1–2 bractlets; perianth 4-parted; stamens 4; filaments short. Pistillate catkins erect; flowers 2–3 in the axil of each bract; perianth replaced by 2–4 minute bractlets which are adherent to the bract. Ovary 2-celled; styles 2. Fruit a winged or angled nut; bracts of the pistillate flowers somewhat fleshy, persistent, becoming woody in fruit.*

1. A. incana Mœnch. SPECKLED ALDER. A shrub 8–20 ft. high. Leaves broadly oval or ovate, rounded at the base, sharply (sometimes doubly) serrate, white and usually downy beneath. Fruit round. Forming thickets by streams, very common N.

2. A. rugosa Spreng. SMOOTH ALDER. A shrub or small tree with smooth bark. Leaves obovate, rounded or obtuse at the apex, acute at the base, sharply and minutely serrate, smooth above, downy beneath, petioled; stipules oval, deciduous. Staminate catkins 2–4 in. long; fruiting catkins ovoid, short-peduncled. Fruit ovate, wingless. Banks of streams and borders of marshes, ranging far S. Leaves often persistent during the winter.*

18. FAGACEÆ. BEECH FAMILY

Trees or shrubs. Leaves alternate, simple, pinnately veined; stipules deciduous. Flowers monœcious, the staminate in heads, or in drooping, spreading, or erect catkins; calyx minute; petals none; stamens 4–20. Pistillate flowers solitary or in small clusters, each flower subtended by more or less united bracts, which at maturity form a cup or bur; calyx minutely toothed; petals none; ovary 2–7-celled, but becoming 1-celled. Fruit a 1-seeded nut.*

I. FAGUS L.

Trees with smooth, close, ash-gray bark, and slender, often horizontal, branches. Staminate flowers in long, slender-peduncled, roundish clusters; calyx bell-shaped, 4–6-cleft; stamens 8–12; anthers 2-celled. Pistillate flowers solitary or more often in pairs, peduncled, surrounded by a 4-lobed involucre and numerous linear bracts; ovaries 3-celled, with 2 ovules in each cell, but usually only 1 ovule maturing in each ovary; styles 3, thread-shaped. Fruit a thin-shelled, 3-angled nut.*

1. F. grandifolia Ehrh. BEECH. Large trees. Leaves oblong-ovate, taper-pointed at the apex, serrate, straight-veined, very white-silky when young, nearly smooth with age. Involucre densely covered with short recurved spines. Nuts thin-shelled, edible. Common on damp soil everywhere. The wood is very hard, tough, and close-grained, and is especially valuable for the manufacture of small tools.*

2. F. sylvatica L. The European beech is occasionally found planted as a shade tree. The variety known as the copper beech is most usual, and is readily recognized by its dark, crimson-purple leaves.

II. CASTANEA Hill

Trees or shrubs with rough, gray, rather close bark. Leaves straight-veined, undivided, prominently toothed. Flowers appearing later than the leaves. Staminate catkins erect or spreading, loosely flowered, flowers several in the axil of each bract; calyx 4–6-parted; stamens 8–16. Pistillate flowers at the base of the staminate catkin or in small separate clusters, usually 3 in each involucre; ovary 4-celled, surrounded by 5–12 abortive stamens. Fruit a 1-celled nut inclosed in the greatly enlarged and very prickly involucre.*

1. C. dentata Borkh. AMERICAN CHESTNUT. A large tree, bark somewhat rough, and splitting into longitudinal plates. Leaves oblong-lanceolate, taper-pointed at the apex, usually acute at the base, coarsely and sharply serrate with ascending teeth, smooth, dark green above, lighter below; petioles stout, short. Staminate catkins erect, 6–10 in. long. Nuts usually 3 in each bur. Rich soil, especially N. Rarely found on soils containing much lime.*

2. C. pumila Mill. CHINQUAPIN. A small tree or shrub. Leaves oblong, acute or obtuse at both ends, serrate with divergent teeth, dark green and smooth above, white-woolly below. Nuts solitary, nearly globular. Common southward in rich woods.*

III. QUERCUS L.

Trees or shrubs with entire, serrate, or lobed leaves, which are often persistent. Staminate flowers in slender catkins, each subtended by quickly deciduous bracts, and consisting of 3–12 stamens inclosed by a 4–8-parted perianth, often containing an abortive ovary. Pistillate flowers solitary or in small clusters, each consisting of a 3-celled ovary with 2 ovules in each cell, though rarely more than 1 ovule matures; styles short, erect, or recurved. Pistillate flowers surrounded by a scaly involucre which at maturity becomes a cup inclosing the base of the fruit or sometimes a large part of it. Fruit an ovoid or subglobose, 1-seeded, thin-shelled nut (acorn).

A. Fruit annual; leaves not bristle-tipped, though often mucronate.

1. Q. alba L. WHITE OAK. A large tree with light gray bark. Leaves obovate-oblong, 3–9-lobed, lobes rounded and mostly entire, bright green above, paler below, short-petioled. Cup hemispherical, scales rough, woolly when young, but becoming smooth with age; acorn oblong-ovate, about 1 in. long. Common in damp soil. Wood strong and durable; one of the most valuable timber trees.*

2. Q. stellata Wang. POST OAK. A tree of medium size with rough gray bark. Leaves broadly obovate, deeply lyrate-pinnatifid into 5–7 rounded, divergent lobes, upper lobes much the longer, smooth above, yellowish-downy beneath; petioles about 1 in. long. Cup hemispherical, nearly sessile; acorn ovoid, 2–3 times as long as the cup. On dry soil. Wood hard and valuable.

3. Q. lyrata Walt. SWAMP OAK. A large tree with gray or reddish bark. Leaves obovate-oblong, deeply pinnatifid, lobes narrow, often toothed, thin, smooth above, white, densely woolly beneath. Cup round-ovate, scales cuspidate, inclosing nearly the whole of the depressed-globose acorn. On wet soil. Wood strong and very durable.*

4. Q. macrocarpa Michx. BUR OAK. A medium-sized to very large tree, with roughish gray bark. Leaves obovate or oblong, lyrately and deeply sinuate-lobed, smooth above, pale and downy beneath. Cup very deep and thick, abundantly fringed about the margin, $\frac{3}{4}$–2 in. in diameter. Acorn, half or more (sometimes entirely) inclosed by the cup. Reaches its full size only on rich bottom lands S. and W., where it becomes one of the finest timber oaks. Wood very hard and heavy.

5. Q. **Muhlenbergii** Engelm. YELLOW CHESTNUT OAK. A tree of medium or large size with gray bark. Leaves oblong or oblanceolate, usually acute at the apex and obtuse or rounded at the base, coarsely and evenly toothed; veins straight, impressed above and prominent beneath; petioles slender. Cup hemispherical, sessile or short-peduncled, with flat scales, $\frac{1}{2}$ in. broad, inclosing about half the ovoid acorn, which is $\frac{2}{3}$–$\frac{3}{4}$ in. long. Common on dry soil. Wood close-grained, durable, and valuable.

6. Q. **Prinus** L. SWAMP CHESTNUT OAK. A large tree with brown, ridged bark. Leaves oblong or oblong-lanceolate, rather obtuse, crenately toothed, minutely downy beneath; petioles slender, about 1 in. long. Cup hemispherical, peduncles longer than the petioles, scales acute, tubercular, appressed; acorn oblong, acute, 1 in. or less in length, edible. Common on low ground. Wood strong and valuable.*

7. Q. **virginiana** Mill. LIVE OAK. A large tree with rough gray or brown bark and a low, spreading top. Leaves leathery, evergreen, oblong or oblanceolate, often somewhat 3-lobed on young trees, margin rolled under, dark green and shining above, pale below; petioles short, stout. Fruit often in short racemes, cup top-shaped, scales closely appressed, hoary, peduncles $\frac{1}{2}$–1 in. long; acorn from subglobose to oblong, the longer form occurring on the younger trees. On low ground near the coast. Wood very hard and durable; valued for shipbuilding.*

B. Fruit biennial; leaves entire or with bristle-pointed lobes.

8. Q. **rubra** L. RED OAK. A large tree. Leaves oval or obovate, green above, pale and slightly downy beneath; sinuses shallow and rounded, lobes 8–12, taper-pointed; petioles long. Cups saucer-shaped, with fine scales; acorn ovate or oblong, about 1 in. long. Common; wood not valuable; leaves turning red after frost and often remaining on the tree through the winter.

9. Q. **velutina** Lam. BLACK OAK. A large tree with rough, dark brown outer bark and thick, bright yellow inner bark. Leaves broadly oval, usually cut more than halfway to the midrib, sinuses rounded; lobes about 7, sharply toothed at the apex, smooth above, usually downy on the veins beneath; cup hemispherical or top-shaped, with coarse scales, short-peduncled, inclosing about half the roundish acorn. Common; wood not valuable, but the inner bark used for tanning and dyeing.*

10. Q. **falcata** Michx. SPANISH OAK. A small or medium-sized tree with leaves 3–5-lobed at the apex, obtuse or rounded at the base, grayish-downy beneath, lobes lanceolate and often scythe-shaped,

sparingly cut-toothed. Cup top-shaped, with coarse scales, inclosing about half the nearly round acorn. Common in dry woods. Foliage quite variable in outline and lobing; bark valuable for tanning.*

11. Q. nigra L. Black-Jack Oak. A small tree; leaves obovate, usually with three rounded lobes at the apex, the lobes bristle-pointed, rounded, or slightly cordate at the base, rusty-pubescent beneath, shining above, coriaceous, short-petioled; cup top-shaped, short-peduncled, with coarse and truncate scales, inclosing about one third of the oblong-ovate acorn. An almost worthless tree, its presence indicating a thin and sterile soil.*

12. Q. phellos L. Willow Oak. A tree of medium size, leaves lanceolate or elliptical, scurfy when young and becoming smooth with age, very short-petioled; cup shallow, sessile; acorn subglobose. Wet soil. Often planted for shade.*

19. ULMACEÆ. Elm Family

Trees or shrubs with watery juice; alternate, simple, petiolate, serrate, stipulate leaves, which are usually 2-ranked; and small, bisexual, or somewhat monœcious, apetalous flowers. Calyx of 3–9 sepals, which are distinct or partly united; stamens as many as the sepals and opposite them. Ovary 1–2-celled; styles 2, spreading. Fruit a key, nut, or drupe.*

I. ULMUS L.

Trees with straight-veined, unsymmetrical, doubly serrate leaves; stipules early deciduous. Flowers bisexual; calyx bell-shaped, 4–9-cleft. Stamens slender, protruding. Ovary compressed; styles 2, spreading. Fruit membranaceous, flat, winged on the edge.*

1. U. fulva Michx. Slippery Elm. A tree of medium size, with rough, downy twigs, and rusty, densely woolly bud scales. Leaves large, thick, very rough above, downy beneath, ovate or obovate, taper-pointed at the apex, unsymmetrical, obtuse or somewhat cordate at the base, coarsely and doubly serrate; calyx lobes and pedicels downy. Fruit broadly oval, downy over the seed, the wing smooth. Inner bark very fragrant when dried, and a popular domestic remedy.*

2. U. campestris L. English Elm. A large tree, with short, rather upright or ascending branches. Leaves not bilaterally symmetrical, oval, acute or sometimes a little taper-pointed, doubly

serrate, 3–4 in. long. Flowers in close clusters with very short pedicels. Fruit obovate-elliptical, with a fissure extending almost to the seed, nearly smooth and not ciliate. Considerably planted as a shade tree and rarely escaped from cultivation. Very variable, one variety with thick ridges of cork on the twigs.

3. U. americana L. WHITE ELM. A large tree with gray bark, drooping branches, and smooth or slightly downy twigs. Leaves oval or obovate, abruptly taper-pointed at the apex, obtuse and oblique at the base, slightly rough above, soft-downy or soon smooth beneath. Flowers in close fascicles; pedicels slender, smooth. Fruit oval or obovate, with 2 sharp teeth bending toward each other at the apex;

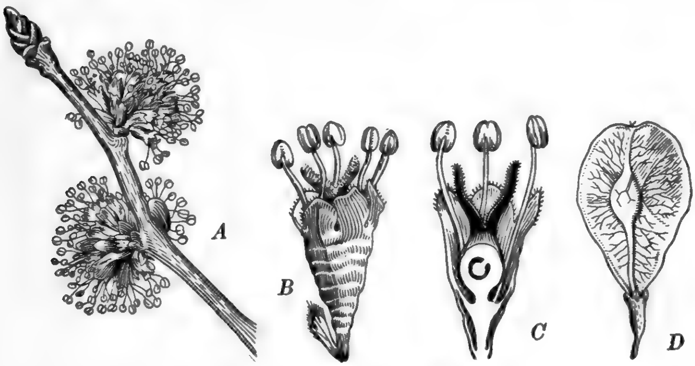


FIG. 12. *Ulmus campestris*

A, a flowering twig; *B*, a flower; *C*, longitudinal section of a flower; *D*, a fruit. (*A*, *D*, natural size; *B*, *C*, enlarged.) (After Wossidlo)

wing reticulate-veined, downy on the margin. In moist, rich soil. A widely planted ornamental tree; wood strong but warping badly, and not durable when exposed.*

4. U. racemosa Thomas. CORK ELM, ROCK ELM. A large tree 80–100 ft. high, with the young twigs somewhat downy; the branches often with ridges of cork. Leaves much as in *U. americana*, but smaller and less sharply serrate. Flowers racemed, on thread-like pedicels. Fruit oval, downy on the surface and densely ciliate. In rich soil, especially along river banks. A highly valuable timber tree.

5. U. alata Michx. WINGED ELM. A small tree with branches corky-winged. Leaves small, ovate-lanceolate, acute, sharply serrate, base nearly equal-sided, rough above, downy beneath, nearly sessile.

Flowers in small clusters. Fruit oblong, downy on the sides, ciliate on the edges. On rich soil. Occasionally producing a second set of flowers and fruit from September to November.*

II. CELTIS L.

Trees or shrubs with entire or serrate, petioled leaves. Flowers greenish, axillary, on wood of the same season, the staminate in small clusters, the fertile single or 2–3 together.*

1. C. occidentalis L. HACKBERRY. A large or medium-sized tree, having much the appearance of an elm, bark dark and rough. Leaves ovate, taper-pointed at the apex, abruptly obtuse and inequilateral at the base, sharply serrate, often 3-nerved from the base, smooth above, usually somewhat downy below. Fruit a small, dark-purple drupe. On rich soil.

2. C. mississippiensis Bosc. SOUTHERN HACKBERRY. A tree usually smaller than the preceding, bark gray, often very warty. Leaves broadly lanceolate or ovate, long taper-pointed at the apex, obtuse or sometimes heart-shaped at the base, entire or with very few serratures, smooth on both sides, 3-nerved. Fruit a purplish-black, globose drupe.*

20. MORACEÆ. MULBERRY FAMILY

Trees, shrubs, or herbs, usually with milky juice, alternate leaves, large deciduous stipules, and small monœcious or diœcious flowers crowded in spikes, heads, or racemes, or inclosed in a fleshy receptacle. Staminate flowers with a usually 4-lobed calyx, and with as many stamens opposite the lobes; filaments usually inflexed in the bud, straightening at maturity. Pistillate flowers usually 4-sepalous; ovary 1–2-celled, 1–2-ovuled; styles 2; receptacle and perianth often fleshy at maturity.*

I. MORUS L.

Trees or shrubs with milky juice, rounded leaves, and monœcious flowers in axillary spikes. Staminate flowers with a 4-parted perianth, and 4 stamens inflexed in the bud. Pistillate flowers with a 4-parted perianth, which becomes fleshy in the multiple fruit, the pulpy part of which consists of the

thickened calyxes of many flowers; ovary sessile; stigmas 2, linear, spreading; the fleshy perianth inclosing the ovary at maturity.*

1. M. rubra L. Red Mulberry. A small tree. Leaves cordate-ovate, often 3–5-lobed on vigorous shoots, taper-pointed at the apex, serrate, rough above, white, densely woolly beneath. Mature fruiting spikes oblong, drooping, dark red or purple, edible. On rich soil. Wood very durable, bearing exposure to the weather.

2. M. alba L. White Mulberry. A small tree. Leaves ovate, heart-shaped, acute at the apex, rounded and often oblique at the base, serrate or sometimes lobed. Smooth and shining on both sides. Mature fruit light red or white. Introduced and common about old dwellings.*

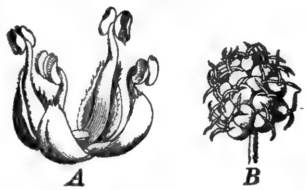


Fig. 13. *Morus alba*

A, staminate flower, about four times natural size; *B*, cluster of pistillate flowers. (After Warming)

II. MACLURA Nutt. (TOXYLON)

A small tree with milky juice. Leaves alternate, petioled, spines axillary. Flowers diœcious. Staminate flowers in short axillary racemes; calyx 4-parted; stamens 4, inflexed in the bud. Pistillate flowers in axillary, peduncled, capitate clusters; calyx 4-parted; ovary sessile; style long; calyxes becoming thickened and fleshy in fruit and aggregated into a large, dense, globular head.*

1. M. pomifera Schneider. Osage Orange. A small tree with ridged, yellowish-brown bark. Leaves minutely downy when young, becoming smooth and shining with age, ovate or ovate-oblong, taper-pointed at the apex, obtuse or subcordate at the base, entire, petioled. Staminate racemes about 1 in. long. Pistillate flower clusters about 1 in. in diameter. Fruit yellowish, tubercled, 3–4 in. in diameter. In rich soil. Native in Texas and extensively planted for hedges. Wood very durable when exposed to the weather, and therefore used for fence posts. As the wood does not swell or shrink with changes in its moisture, it is highly valued for wheel hubs, etc.*

III. BROUSSONETIA L'Her.

Small trees with milky juice. Leaves alternate, petioled. Flowers diœcious; staminate in cylindrical spikes, with a

4-cleft calyx, 4 stamens, and a rudimentary ovary; pistillate flowers in capitate clusters, calyx 3–4-toothed. Ovary stalked; style 2-cleft. Fruit in a globular head.*

1. **B. papyrifera** Vent. PAPER MULBERRY. A round-topped tree with yellowish-brown bark. Leaves cordate, often irregularly 2–3-lobed, serrate, rough above, downy beneath, long-petioled. Staminate spikelets peduncled, 2–3 in. long. Pistillate heads stout, peduncled, about 1 in. in diameter. Introduced from Asia and very common S. about old dooryards.*

IV. CANNABIS L.

Coarse herbs with very tough, fibrous bark. Leaves usually opposite, palmately compound. Flowers small, diœcious, greenish, the staminate ones in compound racemes or panicles, the pistillate ones in spikes. Calyx of the staminate flowers of 5 sepals, that of the pistillate flowers of 1 large sepal which covers the ovary and the akene.

1. **C. sativa** L. COMMON HEMP. An erect plant, 4–8 ft. high. Leaves large, petioled, of 5–7 lanceolate, irregularly serrate or toothed leaflets. Cultivated from Europe, S. and W., for its fiber, and sometimes runs wild along roadsides in rich soil.

21. URTICACEÆ. NETTLE FAMILY

Herbs with watery juice, stem and leaves often clothed with stinging hairs. Leaves undivided, stipulate. Flowers small, greenish, unisexual, apetalous in axillary clusters. Calyx of the staminate flowers 4–5-parted or 4–5-sepalous; stamens as many as the sepals and opposite them; filaments inflexed in the bud and straightening at maturity; anthers 2-celled. Calyx of pistillate flowers 2–4-sepalous; ovary sessile, 1-celled; stigma simple or tufted. Fruit an akene commonly inclosed in the dry, persistent calyx.*

URTICA L.

Annual or perennial herbs. Leaves with stinging hairs, opposite, petioled, several-nerved, dentate or incised, stipulate. Flowers monœcious or diœcious. Calyx of the staminate

flowers 4-parted; stamens 4, inserted around a rudimentary ovary. Pistillate flowers with 4 unequal sepals, the inner ones dilated in fruit; akenes smooth, compressed.*

1. U. gracilis Ait. SLENDER NETTLE. Perennial, slender, with some stinging hairs, 2–6 ft. high. Leaves ovate-lanceolate or narrower, with slender petioles, taper-pointed, sharply serrate, with 3–5-nerves arising from the rounded or sometimes almost heart-shaped base, almost smooth; stipules lanceolate. Flower clusters in branching panicled spikes, longer than the petioles. Flowers diœcious or bisexual.

2. U. urens L. SMALL NETTLE. Annual; stem stout, 4-angled, hairy, 12–18 in. tall, with few stinging hairs; branches slender. Leaves elliptical or ovate, serrate or incised, 3–5-nerved, acute or obtuse at the ends, thin, hairy; petioles often as long as the blades; stipules short. Flower clusters axillary, in pairs, loose, mostly shorter than the petioles. On damp soil in waste places. Naturalized from Europe.

22. SANTALACEÆ. SANDALWOOD FAMILY

Herbs, shrubs, or trees with entire leaves. Flowers usually small. Calyx 4–5-cleft, its limb epigynous. Corolla wanting. Stamens as many as the calyx lobes and opposite them, inserted on the margin of a fleshy disk. Style 1; ovary 1-celled, with 2–4 ovules borne at the top of a free central placenta. Fruit 1-seeded.

COMANDRA Nutt.

Low, smooth perennials with herbaceous stems, rather woody below, often parasitic. Leaves alternate and nearly sessile. Flowers nearly white, in small umbel-like clusters, bisexual. Calyx bell-shaped at first. Stamens borne on a 5-lobed disk which surrounds the pistil; anthers connected by a tuft of hairs to the calyx lobes.

1. C. umbellata Nutt. BASTARD TOADFLAX. Plant 8–10 in. high, with very leafy stems. Roots attached to the roots of trees, from which they draw nourishment. Leaves oblong or oblanceolate, pale, nearly 1 in. long. Umbel-like clusters about 3-flowered, longer than the leaves. Rocky, dry woods.

23. LORANTHACEÆ. Mistletoe Family

Parasitic shrubs or herbs, leaves opposite, leathery, without stipules. Flowers monœcious or diœcious, clustered or solitary; perianth of both calyx and corolla, or of a calyx only, or sometimes wanting, the limb epigynous; sepals 2–8. Stamens as many as the sepals, and opposite them. Ovary 1-celled; ovule 1. Fruit a berry.*

PHORADENDRON Nutt.

Evergreen, shrubby plants, parasitic on trees; branches greenish, jointed, and very brittle. Leaves leathery. Flowers diœcious, in short jointed spikes. Staminate flowers globular, calyx 2–4-lobed, stamens sessile at the base of the lobes, anthers transversely 2-celled. Stigma sessile. Berry 1-seeded.*

1. **P. flavescens** Nutt. American Mistletoe. Very round, bushy; branches very brittle at the joints, opposite or whorled, 6 in. to 2 ft. long. Leaves flat, leathery, or somewhat fleshy, nearly veinless, obovate, entire, with short petioles. Flowering spikes solitary or 2–3 together in the axils of the leaves. Berry roundish, white, glutinous. Parasitic on many deciduous trees.*

24. ARISTOLOCHIACEÆ. Dutchman's Pipe Family

Herbaceous plants, apparently stemless or with twining and leafy stems. Leaves alternate, without stipules, petioled, mostly roundish or kidney-shaped. Flowers axillary, solitary or clustered, bisexual. Calyx tubular, 3- or 6-lobed, usually colored. Petals none. Stamens 6–12, epigynous. Pistil 1; ovary mostly 6-celled, many-seeded.*

I. ASARUM L.

Perennial, apparently stemless, aromatic herbs, with slender, branching rootstocks. Leaves long-petioled, from kidney-shaped to halberd-shaped. Flowers axillary, peduncled. Calyx actinomorphic, 3-lobed, withering-persistent. Stamens 12, the filaments partially united with the style and usually prolonged beyond the anthers. Ovary 6-celled, with parietal placentæ, many-seeded. Mature capsule roundish, often somewhat fleshy.*

1. A. canadense L. WILD GINGER. Plant soft-hairy. Leaves 2, large, kidney-shaped, on long petioles, with the flower borne on a short peduncle between them. Flower greenish outside, brownish-purple inside. Calyx lobes epigynous, taper-pointed, widely spreading, relaxed at the tip. Rich, shady woods, common N.

2. A. virginicum L. VIRGINIA ASARUM. Leaves evergreen, 1–3 to each plant, smooth, mottled, round-cordate, entire, 2–3 in. long and broad; petioles smooth or downy along one side, 3–7 in. long. Flowers nearly sessile, greenish without, dull purple within, $\frac{2}{3}$–$\frac{3}{4}$ in. long; tube inflated below, narrow at the throat, lobes spreading. Rich, shady woods.*

II. ARISTOLOCHIA L.

Erect or twining perennial herbs or woody vines. Leaves alternate, heart-shaped at the base, palmately nerved, petioled, entire. Flowers zygomorphic, solitary, or in small clusters. Calyx perigynous or epigynous, tubular, irregular. Stamens mostly 6, sessile, apparently united to the angled and fleshy 3–6-lobed or -angled stigma. Capsule naked, 6-valved; seeds very numerous.*

1. A. macrophylla Lam. DUTCHMAN'S PIPE, PIPE VINE. A tall climber. Leaves dark green, smooth, round-kidney-shaped, sometimes 1 ft. wide. Peduncles 1-flowered, with a single clasping bract. Calyx $1\frac{1}{2}$ in. long, bent into the shape of a pipe, its border abruptly spreading, brownish-purple. Rich woods, often cultivated.

2. A. tomentosa Sims. DUTCHMAN'S PIPE. Stem woody, climbing high, branches and leaves densely woolly. Leaves heart-shaped, prominently veined, 3–5 in. long and broad. Flowers axillary, mostly solitary, on slender peduncles. Calyx bent in the shape of a pipe, yellowish-green with a dark purple throat, limb unequally 3-lobed, rugose, reflexed. Anthers in pairs below the 3 spreading lobes of the stigma. Capsule oblong. Stems sometimes 30 ft. long. Rich woods S.*

25. POLYGONACEÆ. BUCKWHEAT FAMILY

Herbs with alternate, entire leaves, and usually with sheathing stipules above the swollen joints of the stem. Flowers apetalous, generally bisexual, with a 3–6-cleft calyx, generally colored and persistent. Fruit a compressed or 3-angled akene, inclosed in the calyx; seeds with endosperm, which does not generally inclose the embryo. Stamens 4–12, on the base of the calyx.

I. RUMEX L.

Coarse herbs, many of them troublesome weeds. Flowers small, usually green or greenish, generally in whorls borne in panicled racemes. Calyx of 6 nearly distinct sepals, the 3 inner ones larger and more petal-like than the 3 outer, and one or more of them usually with a little knob or tubercle on its back. Stamens 6; styles 3; stigmas short, fringed. Fruit a 3-angled akene, closely covered by the 3 inner calyx lobes, enlarged and known as valves.

1. R. crispus L. Yellow Dock. Stout, smooth, 3–4 ft. high. Leaves lanceolate, margins very wavy, acute, the lower more or less heart-shaped. Root long, tapering gradually downward, yellow, very tough. Flowers in whorls crowded in long, straight, slender racemes. Valves roundish-heart-shaped, mostly tubercled. A very hardy weed, naturalized from Europe.

2. R. verticillatus L. Swamp Dock. Perennial. Stem stout, smooth, erect or ascending, 3–5 ft. tall. Lower leaves oblong, obtuse at the apex and usually heart-shaped at the base, long-petioled, often 12–18 in. long; upper leaves narrower and often acute at both ends. Flowers bisexual or somewhat monœcious, in dense whorls; pedicels slender, $\frac{1}{2}$–$\frac{2}{3}$ in. long, tapering downward, reflexed at maturity. Calyx green, the valves broadly triangular, abruptly pointed, reticulated, a distinct long and narrow tubercle on the back of each. Swamps and wet ground.*

3. R. Acetosella L. Sheep Sorrel. Perennial herbs with slender creeping and bud-bearing roots. Stem simple or branched, smooth. Leaves petioled, narrowly halberd-shaped, usually widest above the middle, the apex acute or obtuse; upper stem leaves often nearly linear and not lobed. Flowers diœcious, small, in terminal, naked, panicled, interrupted racemes. Calyx greenish; the pistillate panicles becoming reddish. Fruit less than $\frac{1}{12}$ in. long, granular, longer than the calyx. A common weed, naturalized from Europe, in dry fields and on sour soils. Foliage very acid.*

II. POLYGONUM L.

Annual or perennial, terrestrial or aquatic herbs, with enlarged joints and simple, alternate, entire leaves; the sheathing stipules often cut or fringed. Flowers bisexual, usually white or rose-colored, each flower or cluster subtended by a membranaceous bract similar to the stipules of the leaves.

Calyx mostly 5-parted, the divisions petal-like, erect and persistent. Stamens 3–9; styles 2–3-parted. Fruit lens-shaped or 3-angled.*

1. P. aviculare L. KNOTGRASS. Annual or perennial. Stem prostrate or ascending, diffuse, smooth, 6–24 in. long. Leaves small, lanceolate or linear-oblong, obtuse, nearly or quite sessile. Sheaths thin and dry, 2–3-cleft or cut. Flower clusters axillary, 1–5-flowered; flowers inconspicuous, nearly sessile. Calyx greenish-white, 5-parted, the lobes with white or colored borders. Stamens 5–8; style 3-parted. Akene 3-angled, not shining. A common weed in dooryards and where the ground is trampled.*

2. P. lapathifolium L. Annual. Stem branching, 1–4 ft. high. Leaves lanceolate or broader, wedge-shaped at the base and tapering from near the base to an extremely slender point, ciliate, varying greatly in length. Sheaths not ciliate or fringed. Spikes oblong to linear, closely flowered, erect or nearly so, $\frac{1}{2}$–2 in. long. Calyx white or pink. Stamens 6; style 2-cleft. Akene ovate, lens-shaped, $\frac{1}{12}$ in. wide or less. In wet soil.

3. P. acre HBK. WATER SMARTWEED. Perennial. Smooth or nearly so; stems erect or ascending, rooting below, 2–5 ft. high. Leaves lanceolate or broader, tapering at both ends, petioled, ciliate, translucent-dotted, acrid, 1$\frac{1}{2}$–8 in. long. Sheaths cylindrical, falling early, bristly-fringed. Spikes erect or nearly so, loosely flowered, $\frac{3}{4}$–3 in. long. Calyx whitish-greenish or flesh color. Stamens 8; style usually 3-parted. Akene oblong, lens-shaped, smooth and shining. Swamps and wet soil, especially S.

4. P. Persicaria L. LADY'S THUMB. Annual. Smooth or nearly so. Stem erect or ascending, 6–24 in. high. Leaves lanceolate or narrower, tapering at both ends, usually with a dark triangular or crescent-shaped spot near the center, very variable in length. Sheaths more or less bristle-fringed. Spikes ovoid or oblong, dense, erect, peduncled, $\frac{3}{8}$–2 in. long. Calyx pink or purple. Stamens usually 6; styles 2–3-cleft more than half their length. Akene broadly ovate and lens-shaped, often somewhat triangular, smooth and shining. In waste ground, often a troublesome weed. Naturalized from Europe.

5. P. hydropiperoides Michx. MILD WATER PEPPER. Perennial. Stem smooth, slender, erect, decumbent, or prostrate, 1–3 ft. long. Leaves usually narrowly lanceolate, but variable, acute, ciliate, 2–6 in. long. Sheaths wrinkled, bristle-fringed. Spikes erect, slender, often with the flowers scattered, $\frac{1}{2}$–2$\frac{1}{2}$ in. long. Calyx pale pink, greenish or nearly white. Stamens 8; style 3-parted more than half its length. Akene 3-angled, smooth and shining. In swamps and wet places, especially S.

6. P. dumetorum L. False Buckwheat. Perennial. Stems slender, twining, branched, 2–10 ft. long. Leaves ovate, taper-pointed, heart-shaped to halberd-shaped at the base, long-petioled. Stipules cylindrical, truncate. Flowers in axillary, more or less compound and leafy racemes. Calyx greenish-white, the outer lobes winged and forming a margin on the pedicel. Stamens 8. Stigmas 3. Akene 3-angled, black, smooth, and shining. Margins of fields and thickets.*

III. FAGOPYRUM Hill

Smooth annual herbs, with more or less triangular leaves; the sheathing stipules cylindrical or funnel-shaped. Flowers bisexual, white, greenish or tinged with rose color, in terminal or axillary, often panicled, racemes. Calyx petal-like (Fig. 14), 5-parted. Stamens 8. Styles 3, with knobbed stigmas. Akene 3-angled, much longer than the persistent calyx (Fig. 14).

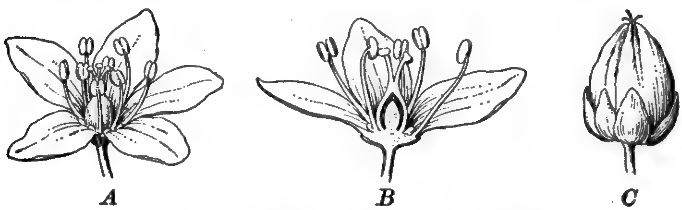


Fig. 14. Buckwheat (*Fagopyrum esculentum*)

A, flower; *B*, section of flower; *C*, fruit. (All somewhat magnified.) (After Marchand)

1. F. esculentum Mœnch. Buckwheat. Annual, nearly smooth. Leaves halberd-shaped, 1–3 in. long. Flowers white or nearly so, with 8 yellow nectar-bearing glands between the stamens. Old fields and thickets, escaped from cultivation. Introduced from Europe or western Asia.

26. CHENOPODIACEÆ. Goosefoot Family

Herbs or shrubs. Leaves simple, alternate, without stipules. Flowers small, actinomorphic, either bisexual or more or less monœcious or diœcious. Calyx free from the ovary. Corolla wanting. Stamens usually 5, opposite the sepals. Styles or stigmas generally 2. Fruit with 1 seed, usually inclosed in a small, bladdery sac, sometimes an akene.

I. SPINACIA L.

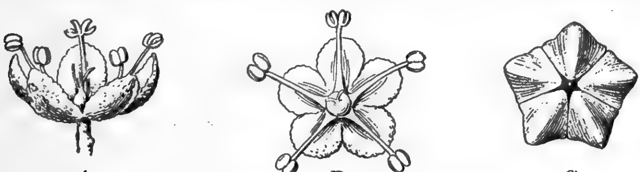
Herbs. Flowers diœcious, in close axillary clusters. Staminate flowers 3–5-sepaled, with 4 or 5 projecting stamens; pistillate flowers with a tubular 2-toothed or 4-toothed calyx.

1. S. oleracea Mill. Spinach. A soft annual or biennial herb. Leaves triangular, ovate, or halberd-shaped, petioled. Cultivated from Asia as a pot herb.

II. CHENOPODIUM L.

Annual or perennial herbs. Stems erect or spreading. Leaves alternate, usually white-mealy. Flowers small, greenish, in panicled spikes. Calyx 3–5-parted, the lobes often slightly fleshy and keeled. Stamens 5; filaments thread-shaped. Styles 2–3, distinct or united at the base. Seed lens-shaped.*

1. C. Botrys L. Jerusalem Oak. A low, spreading plant, covered with sticky down. Leaves with slender petioles, oblong, sinuately



A B C

Fig. 15. Pigweed (*Chenopodium album*)

A, *B*, flower; *C*, fruit. (All about seven times natural size)

lobed or the lobes pinnate. Flowers in loose, diverging, leafless racemes. The whole plant is sweet-scented. Introduced from Europe and naturalized in gardens and along roadsides.

2. C. glaucum L. Oak-Leaved Goosefoot. Annual, succulent, somewhat mealy. Stem spreading, much branched, 5–12 in. high. Leaves varying from oblong to lanceolate, obtuse, some or all of them more or less sinuate-toothed, 1–2 in. long. Flower clusters mostly small axillary spikes. A common weed. Naturalized from Europe.

3. C. album L. Lamb's Quarters. Common Pigweed. Annual, somewhat mealy. Stem erect, usually branching, 1–4 ft. high. Leaves

varying from rhombic-ovate to (the uppermost) nearly linear, narrowed at the base, acute, somewhat angulate-toothed, 1–4 in. long. Spikes terminal and in the leaf axils, often panicled. Calyx with keeled lobes, in fruit nearly covering the smooth seed. A common and troublesome weed. Naturalized from Europe.

4. C. urbicum L. UPRIGHT GOOSEFOOT. Annual, little or not at all mealy. Stem stout, erect, and with erect branches, 1–3 ft. high. Leaves halberd-shaped or triangular, acute, coarsely and sharply toothed, except the upper ones, the larger ones 3–6 in. long. Spikes in a narrow, erect panicle. Lobes of the calyx not keeled. Waste ground. Naturalized from Europe.

27. AMARANTHACEÆ. AMARANTH FAMILY

Mostly herbs, with nearly the characters of the *Chenopodiaceæ,* but with usually 3 dry, translucent, persistent, often colored, bracts beneath the flower. Most of the genera are tropical; our commonest species are troublesome weeds, usually flowering in midsummer or later.

AMARANTHUS L.

Mostly annual herbs. Leaves alternate, simple, thin, usually entire, often bristle-tipped. Flowers mostly 3-bracted, small, green or purplish in our wild species, in axillary clusters or dense terminal spikes. Calyx of 5 or sometimes 3 distinct erect sepals. Stamens distinct, usually 5, anthers 2-celled. Styles or stigmas 2 or 3. Fruit small, bladdery, 1-seeded, with 2 or 3 beaks formed by the withered styles.

1. A. graecizans L. TUMBLEWEED. Smooth, pale green. Stem diffusely branched, whitish, the branches slender, ascending. Leaves small, varying from obovate to spatulate, obtuse or retuse, $\frac{3}{8}$–$1\frac{1}{2}$ in. long. Flowers greenish, in small axillary clusters, covered by stiff, sharp-pointed bracts. Sepals 3. In waste ground and a common field and garden weed. In the autumn the leaves drop and the globular stem and branches roll freely about before the wind.

2. A. spinosus L. SPINY AMARANTH. Stem stout, ridged, smooth, bushy-branched, often red, 1–4 ft. high. Leaves varying from ovate to lanceolate, tapering to both ends, dull green, $\frac{3}{4}$–3 in. long, each with a pair of stiff spines in its axil. Flower clusters of two sorts,

the upper ones of staminate flowers in long slender spikes, the axillary ones globular, composed of pistillate flowers. Bracts lance-awl-

FIG. 16. Prince's feather (*Amaranthus hypochondriacus*)

A, staminate flower; *B*, pistillate flower; *C*, fruit. (All magnified.) (After Schnizlein)

shaped about the length of the 5 sepals. In waste ground, fields, and gardens. Naturalized from tropical America.

A. retroflexus L. and **A. hybridus** L., usually known as pigweed, are common autumn-flowering weeds.

28. PHYTOLACCACEÆ. Pokeweed Family

Plants with alternate entire leaves. Flowers bisexual, 5-parted, with the characters of the Goosefoot Family, but the ovary generally consisting of several carpels, which unite to form a berry.

PHYTOLACCA L.

Perennial herbs. Stems tall, branching. Leaves large, entire. Flowers small, in terminal racemes, pedicels bracted. Calyx of 4–5 nearly equal, persistent sepals. Stamens 5–15, inserted at the base of the calyx. Styles 5–12, recurved at the apex. Fruit a depressed-globose, juicy berry.*

1. P. decandra L. Pokeweed. Stems erect, smooth, branched above, usually dark purple, 4–7 ft. tall; root large, fleshy, poisonous. Leaves ovate-lanceolate, smooth, acute, long-petioled. Racemes peduncled, many-flowered, opposite the leaves; flowers white, becoming purplish. Stamens 10, shorter than the sepals. Styles 10, carpels 10.

Fruit a dark purple berry. A weed on waste ground. The young branches are often eaten like asparagus, and the root, known as "garget root," is used in medicine.*

29. AIZOACEÆ. Ice Plant Family

Mostly fleshy plants, mainly natives of Africa. Flowers often large and showy. Stamens often doubled and some of them petal-like. Ovary 2–many-celled.

[Our only very common genus belongs to a subfamily which has little resemblance to the fleshy "ice plants," found in some gardens, which best represent the family as a whole.]

MOLLUGO L.

Low branching annuals. Sepals 5, greenish outside, white inside. Corolla wanting. Stamens 5, alternate with the sepals, or 3, alternate with the cells of the ovary. Capsule 3-celled, many-seeded.

1. **M. verticillata** L. Carpet Weed. Stems branching and forming radiating patches. Leaves clustered in apparent whorls at the joints of the stem, spatulate. Flowers in little sessile umbels at the joints. Stamens commonly 3. A troublesome weed in sandy soil and common on sandy beaches and river banks.

30. PORTULACACEÆ. Purslane Family

Generally herbs. Leaves opposite or alternate, entire; stipules dry and membranaceous. Sepals 2. Petals 4 or more, distinct or united below. Stamens 4 or more, hypogynous or perigynous. Ovary usually superior, 1-celled; style simple or 3-cleft; ovules 2–many. Capsule opening transversely with a lid, or 2–3-valved.

I. CLAYTONIA L.

Perennial. Stem simple, smooth, erect, 4–10 in. high. Leaves 2, opposite, smooth, succulent. Flowers in a terminal raceme. Sepals 2, ovate, persistent. Petals 5, sometimes joined at the base. Stamens 5, somewhat perigynous. Style 3-cleft; ovary 1-celled, 3–6-seeded.

1. **C. virginica** L. Spring Beauty. Stem simple, erect from a deep, tuberous root. The 2 stem leaves narrowly elliptical, 3–6 in. long, smooth, fleshy; basal leaves occasionally produced. Flowers on short pedicels. Petals white or pink, with darker veins, $\frac{1}{4}$–$\frac{3}{8}$ in. long, notched. Capsules shorter than the persistent sepals. Common in rich woods.*

2. **C. caroliniana** Michx. Northern Spring Beauty. Flowers fewer, smaller, and whiter than in No. 1, fragrant. Leaves 1–2 in. long, ovate-lanceolate or spatulate, rather distinctly petioled. Moist woods, especially N.

II. PORTULACA L.

Annual. Stems low, diffuse, and spreading, fleshy. Leaves entire, mostly alternate. Flowers terminal, perigynous. Sepals 2, united at the base. Petals usually 5, quickly withering. Stamens 8–20. Style 3–8-parted. Capsules globose, opening by the upper portion coming off like a lid, 1-celled, many-seeded.*

1. **P. oleracea** L. Purslane. Stems prostrate, diffuse, fleshy. Leaves alternate, flat, obovate or wedge-shaped. Flowers solitary, sessile, opening in bright sunshine in the morning and usually withering before noon. Sepals broad, acute. Petals yellow. Stamens 10–12. Capsule very many-seeded, seeds small, wrinkled. A common garden weed.*

2. **P. grandiflora** Hook. Garden Portulaca. Stems fleshy, erect or ascending, densely hairy or nearly smooth, 3–6 in. long. Leaves alternate, cylindrical, fleshy, $\frac{1}{2}$–1 in. long. Flowers 1–2 in. wide, white, yellow, or red, showy, opening only in sunlight. Common in cultivation and often growing spontaneously.*

31. CARYOPHYLLACEÆ. Pink Family

Herbs sometimes woody below, with thickened nodes. Leaves opposite, entire; stipules small and dry or none. Sepals 4–5. Petals 4–5 (rarely 0), usually hypogynous. Stamens usually 8–10, hypogynous or perigynous. Styles 2–5 (rarely 1). Ovules 1–many. Fruit usually a capsule.

A

Sepals distinct or nearly so. Petals (if any) without claws. Capsules several–many-seeded.

Styles usually 3. Capsule ovoid. Stellaria, I

Styles 5 or 4. Capsule cylindrical. Cerastium, II

B

Sepals more or less united. Petals with claws. Capsule several–many-seeded.

(*a*) Calyx without bracts, its lobes long and leaf-like.
Agrostemma, III

(*b*) Calyx without bracts, lobes not leaf-like. Styles 3 or 4.
Silene, V

(*c*) Calyx without bracts, lobes not leaf-like. Styles 5 (rarely 4).
Lychnis, IV

(*d*) Calyx with little bracts at the base. Styles 2.
Dianthus, VI

I. STELLARIA L. (ALSINE)

Slender, usually smooth herbs. Flowers small, white, solitary, or in forking cymes. Sepals 5 (rarely 4). Petals 5 (rarely 4), 2-cleft or -divided. Stamens 10 (rarely 8, 5, or 3), maturing in 2 sets. Styles 3 (rarely 4 or 5), opposite the same number of petals; ovary 1-celled, many-ovuled. Capsule short, splitting into as many valves as there are styles.

1. S. longifolia Muhl. Long-leaved Stitchwort. Stem slender, usually erect, 8–18 in. high, often sharply 4-angled. Leaves linear or nearly so, spreading. Flower clusters peduncled, many-flowered, the pedicels spreading. Petals 2-parted, at length longer than the calyx. Perennial in meadows and grassy thickets, especially N.

2. S. graminea L. Smooth, weak, ascending. Stem sharply 4-angled, 12–20 in. long. Leaves linear-lanceolate or broader, widest a little above the base, ciliate, acute, $\frac{3}{4}$–$1\frac{1}{4}$ in. long. Cyme loose, with slender, widely spreading pedicels. Flowers $\frac{1}{4}$–$\frac{3}{4}$ in. in diameter. Sepals and petals about equal in length, the petals cleft almost to the base. Seeds with many minute tubercles. Fields and roadsides, often among grass. Naturalized from Europe.

3. S. media Cyrill. Common Chickweed. Stem prostrate, 6–18 in. long, with a line or two of hairs along it. Leaves ovate, taper-pointed, the lower petioled, the upper sessile. Petals shorter than the sepals, sometimes wanting. An annual weed, naturalized from Europe, common in damp, shady places N.

II. CERASTIUM L.

Annual or perennial. Stems diffuse, usually downy; leaves opposite. Flowers white, peduncled, in terminal, regularly

forking cymes. Sepals 4–5. Petals 4–5, notched or 2-cleft. Stamens 10. Styles 5 or less. Capsules cylindrical, 1-celled, many-seeded.*

1. C. arvense L. FIELD CHICKWEED. Perennial. Stems tufted, erect or ascending, 4–10 in. high. Basal leaves and those of flowerless branches linear-oblong, crowded; those of flowering stems linear or lance-linear. Flowers $\frac{1}{2}$–$\frac{2}{3}$ in. in diameter, in cymes. Petals obcordate, much longer than the sepals. Pods hardly longer than the calyx. In dry or rocky soil.

2. C. vulgatum L. MOUSE-EAR CHICKWEED. Annual or sometimes perennial. Stems diffuse, tufted, clammy-downy, 6–12 in. high. Lower leaves spatulate, the upper oblong, acute, or obtuse; bracts thin and dry. Flowers in loose cymes, pedicels becoming much longer than the calyx. Sepals lanceolate, acute, about as long as the 2-cleft petals. Slender capsule becoming twice as long as the calyx and curved upward. A common garden weed.*

3. C. brachypodum Robinson. Annual. Stems 3–10 in. high, clammy-downy. Lower leaves oblanceolate or spatulate, the upper ones linear to lanceolate. Pedicels shorter or not much longer than the calyx. Petals longer than the sepals. Capsule straight or slightly curved upwards. In dry soil.

III. AGROSTEMMA L.

Annual. Stem pubescent, branching above. Leaves linear-lanceolate or linear, pubescent, sessile. Flowers showy, on long and naked peduncles in terminal corymbs. Calyx tubular, the tube oblong, 10-ribbed; lobes elongated, leaf-like, deciduous. Petals 5, shorter than the calyx lobes, entire. Stamens 10. Styles 5, capsules 1-celled.*

1. A. Githago L. CORN COCKLE. Stem erect, rather slender, 1–3 ft. tall, gray, with long, appressed hairs. Leaves linear-lanceolate, acuminate, erect, 2–4 in. long. Petals obovate, notched, purple. Capsule 5-toothed, many-seeded; seeds black. An introduced weed, common in grain fields.*

IV. LYCHNIS L.

Plants with nearly the same characteristics as *Silene*, but usually with 5 styles.

1. L. Coronaria Desr. MULLEIN PINK. A forking perennial plant, 2 ft. high, covered with white, cottony down. Leaves very wavy,

spatulate; stem leaves ovate-lanceolate, wavy, clasping. Peduncles long, 1-flowered. Flowers about $1\frac{1}{4}$ in. broad, deep crimson. Calyx tube very strongly 5-ribbed, with 5 smaller ones between; calyx teeth short and slender. Petals somewhat notched. Cultivated in old gardens; from Europe.

2. L. chalcedonica L. SCARLET LYCHNIS, LONDON PRIDE. A tall, hairy perennial (about 2 ft.). Leaves lance-ovate, somewhat clasping. Flower cluster flat-topped and very dense. Flowers bright scarlet, not very large. Petals 2-lobed. Common in old gardens; from Japan.

3. L. Drummondii Wats. Perennial, erect, glandular-downy and sticky, 1–3 ft. high. Leaves oblanceolate or linear, acute, $\frac{3}{4}$–3 in. long. Flowers few, on slender pedicels, white or purplish, $\frac{3}{8}$–$\frac{3}{4}$ in. long. Petals not much longer than the tubular calyx. Capsule $\frac{1}{2}$–$\frac{2}{3}$ in. long. Seeds with little tubercles. In dry soil W.

V. SILENE L.

Annual or perennial herbs. Stems erect or decumbent and diffuse. Leaves often connate or whorled. Flowers clustered or solitary, usually pink or white. Calyx tubular, more or less inflated, 5-toothed, 10-nerved, bractless. Petals 5, long-clawed, and with the ten stamens inserted at the base of the ovary. Styles 3; ovary 1-celled or 3-celled at the base, opening by 6 teeth, many-seeded. Seeds usually roughened.*

1. S. antirrhina L. SLEEPY CATCHFLY. Stem smooth, slender, 8–30 in. high, sticky in spots. Leaves lanceolate or linear. Flowers rather few and small, panicled. Calyx ovoid. Petals inversely heart-shaped, pink, opening only for a short time in sunshine. Dry waste ground.

2. S. Armeria L. CATCHFLY, NONE-SO-PRETTY. A smooth, erect annual or biennial, 6–15 in. high. Several nodes of the stem are usually covered for part of their length with a sticky substance. Leaves very smooth, with a bloom beneath, lanceolate or oblong-lanceolate, clasping. Flowers showy, dark pink, nearly $\frac{1}{2}$ in. in diameter, in flat-topped clusters. Calyx club-shaped. Petals somewhat notched. Cultivated from Europe and introduced.

3. S. noctiflora L. NIGHT-FLOWERING CATCHFLY. A tall, coarse annual or biennial weed, covered with sticky hairs. Lower leaves spatulate, upper ones lanceolate, pointed. Flowers large, white, opening at night or in cloudy weather. Calyx teeth long, awl-shaped. Petals 2-parted. In fields and gardens. Naturalized from Europe.

4. **S. pennsylvanica** Michx. Wild Pink. A perennial with low, clustered stems (4–8 in.). Basal leaves wedge-shaped or spatulate, those of the stem lanceolate. Flowers medium-sized, clustered. Petals wedge-shaped, notched, pink, with a crown at the throat of the corolla. Gravelly soil E.

5. **S. virginica** L. Fire Pink. A slender perennial, with erect stem, 1–2 ft. high. Basal leaves spatulate, the upper leaves oblong-lanceolate. Flowers few, peduncled, large and showy, bright crimson. Corolla crowned, petals deeply 2-cleft. Woods.

6. **S. latifolia** Britten and Rendle. Snappers, Rattlebox. A perennial branched herb about 1 ft. high. Leaves opposite, smooth, ovate or ovate-lanceolate. Calyx thin and bladdery, beautifully veined. Petals white, 2-cleft. Capsule nearly globular. In fields and along roadsides, especially eastward. Naturalized from Europe.

VI. DIANTHUS L.

Tufted, mostly perennial herbs, often shrubby at the base. Leaves narrow and grass-like. Flowers solitary or variously clustered. Calyx tubular, 5-toothed, with overlapping bracts at the base. Petals 5, with long claws. Stamens 10, maturing 5 at a time. Styles 2; ovary 1-celled. Capsule cylindrical, 4-valved at the top.

1. **D. barbatus** L. Sweet William. Perennial, often in large clumps. Stems erect, branching above, smooth, 1–2 ft. tall. Leaves lanceolate, 2–3 in. long, acute. Flowers crimson-pink, white or variegated, in terminal clusters; bracts linear, as long as the calyx. Common about old gardens; from Europe.*

2. **D. Armeria** L. Deptford Pink. Rather erect, annual, with stiff stems 1–2 ft. high. Leaves very dark green, linear, 1–2 in. long, the lower obtuse, the upper acute. Flowers loosely clustered, small, dark pink. Calyx tube $\frac{1}{2}$–$\frac{3}{4}$ in. long, nearly cylindrical. Petals narrow, speckled with very small whitish dots. In sandy fields eastward. Introduced from Europe; sometimes cultivated.

3. **D. plumarius** L. Common Pink, Grass Pink. Leaves grass-like, with a whitish bloom. Petals white, pink, or variegated, with the limb fringed. Flowers solitary, fragrant. Hardy perennials, cultivated from Europe.

4. **D. Caryophyllus** L. Carnation, Clove Pink. Much like the preceding species, but with larger fragrant flowers; the broad petals merely crenate. Hothouse perennials (some hardy varieties), cultivated from Europe.

32. NYMPHÆACEÆ. Water Lily Family

Perennial aquatic herbs. Leaves usually floating, often shield-shaped. Flowers borne on naked scapes. Floral envelopes and stamens all hypogynous or epigynous. Sepals 3–6. Petals 3–5 or often very numerous. Stamens many. Carpels 3 or more, free or united. Fruit a berry or a group of separate carpels.

I. NYMPHÆA L.

Rootstock horizontal, thick, cylindrical. Leaves heart-shaped, floating or erect. Flowers yellow. Sepals 4–6, green on the outside, obovate, concave. Petals many, hypogynous, the inner ones becoming small and stamen-like. Stamens many, hypogynous. Ovary cylindrical, many-celled; stigma disk-shaped. Fruit ovoid.*

1. N. advena Ait. Yellow Pond Lily, Cow Lily, Spatter-Dock. Leaves oval or orbicular, rather thick, often downy beneath. Flowers bright yellow, 2–3 in. in diameter, depressed-globular. Sepals 6. Petals thick and fleshy, truncate. Stamens in several rows; anthers nearly as long as the filaments. In slow streams and still water.*

II. CASTALIA Salisb.

Rootstock horizontal, creeping extensively. Leaves floating, entire, shield-shaped or heart-shaped. Flowers showy. Sepals 4, green without, white within. Petals many, white, becoming smaller towards the center. Stamens many, the outer with broad and the inner with linear filaments. Ovary many-celled, stigmas shield-shaped and radiating. Fruit berry-like, many-seeded.*

1. C. odorata Woodville and Wood. White Water Lily. Rootstock large, branched but little. Leaves floating, entire, the notch narrow and basal lobes acute, green and smooth above, purple and downy beneath. Petioles and peduncles slender. Flowers white, very fragrant, opening in the morning, 3–5 in. broad. Fruit globose; seeds inclosed in a membranaceous sac. In ponds and still water.*

2. C. tuberosa Greene. Much like No. 1. Rootstock bearing loosely attached, often compound tubers. Leaves round-kidney-shaped, seldom purple beneath. Flowers larger than in No. 1, scentless or nearly so. Slow streams, especially W.

III. NELUMBO Adans.

Rootstock large and stout. Leaves round, shield-shaped, often raised above the water. Flowers large, raised above water at first, but often submerged after blooming. Sepals and petals hypogynous, numerous, the inner sepals and outer petals not distinguishable from each other. Stamens many, hypogynous. Pistils several, 1-ovuled, borne in pits in the flattish upper surface of a top-shaped receptacle, which enlarges greatly in fruit.

1. **N. lutea** Pers. AMERICAN LOTUS, WATER CHINQUAPIN. Rootstock often 3–4 in. in diameter, horizontal. Leaves $1\frac{1}{2}$–$2\frac{1}{2}$ ft. broad, prominently ribbed, with much bloom above, often downy beneath. Petioles and peduncles stout. Flowers pale yellow, 5–9 in. broad. Sepals and petals falling quickly. Fruit top-shaped, 3–4 in. in diameter; the seeds $\frac{1}{2}$ in. in diameter. In ponds and slow-running streams W., introduced from the Southwest.*

33. RANUNCULACEÆ. BUTTERCUP FAMILY

Herbs, rarely shrubs, usually with biting or bitter juice. Leaves basal or alternate (in *Clematis* opposite; stem leaves or involucre whorled in *Anemone*); stipules none or adnate to the petiole. Floral organs all distinct and unconnected. Sepals 5 or more (rarely 2–4), falling early, often petal-like. Petals none, or 5 or more (rarely 3). Stamens many. Carpels many, 1-celled; stigmas simple; ovules 1 or more. Fruit composed of 1-seeded akenes or many-seeded follicles. Seeds small.

A

Flowers zygomorphic.

With a spur.	Delphinium, XII
With a hood.	Aconitum, XIII

B

Flowers actinomorphic.

1. Petals present (in (*c*) not very unlike the stamens).

(*a*) Petals very large and showy.	Pæonia, IX
(*b*) Petals small, tubular at the tip.	Coptis, X
(*c*) Petals narrow, spatulate, on slender claws.	Actæa, XIV
(*d*) Petals prolonged backward into spurs.	Aquilegia, XI
(*e*) Petals flat, with a little scale at the base, inside.	Ranunculus, I

2. Petals none, or very small and stamen-like.
   - (*a*) Sepals yellow. Caltha, VIII
   - (*b*) Sepals greenish or white, falling as the flower opens. Thalictrum, II
   - (*c*) Sepals white or colored, involucre sepal-like. Hepatica, IV
   - (*d*) Sepals 4. Plants climbing. Clematis, VI
   - (*e*) Sepals 5, white. Flowers axillary and terminal. Pods 2-several-seeded. Isopyrum, VII
   - (*f*) Sepals white or colored. Plants not climbing. Akenes more or less tailed with the styles in fruit. Anemone, V
   - (*g*) Sepals 5–10, white. Flowers in an umbel. Roots tuberous. Anemonella, III

I. RANUNCULUS L.

Annual or perennial herbs. Leaves alternate, usually deeply lobed or parted. Flowers axillary or in corymbs, white or yellow. Sepals 3–5. Petals 3–5, flat, with a small pit or scale inside at the narrowed base. Stamens usually numerous. Pistils few or several in a head. Akenes flattened, pointed.*

1. R. pusillus Poir. Low Spearwort. Perennial. Stems several, erect or ascending, branched, smooth, 6–15 in. high. Leaves entire or slightly toothed, the lower round or cordate, long-petioled, the upper lanceolate or elliptical, nearly or quite sessile. Flowers very small, about $\frac{1}{6}$ in. wide, yellow. Petals 1–5, as long as the sepals. Stamens 3–10. Akenes smooth, with a very short point. On muddy banks.*

2. R. abortivus L. Small-Flowered Crowfoot. Perennial. Stems smooth, branching, 12–18 in. high. Basal leaves round-cordate, crenate, petioled. Stem leaves 3–5-parted, with wedge-shaped or linear divisions, sessile. Flowers very small, pale yellow. Sepals reflexed, longer than the petals. Akenes in a globose head, smooth, without a beak. Common on wet ground and waste places.*

3. R. recurvatus Poir. Hooked Crowfoot. Perennial. Stem erect, hairy, 1–2 ft. high. Leaves all nearly alike, petioled, 3–5-lobed, with the lobes wedge-shaped, cut or toothed at the apex. Flowers small, pale yellow. Petals minute, shorter than the reflexed sepals. Akenes in a globular head, smooth, with a slender, recurved beak. On low ground.*

4. R. fascicularis Muhl. Tufted Buttercup. Perennial. Stems clustered from thickened fibrous roots, ascending, 5–9 in. high, covered with close-lying silky hairs. Leaves 3–5-divided, the divisions

lobed and cleft into oblong or linear divisions. Flowers about 1 in. in diameter. Petals 5–7, yellow, spatulate-oblong or obovate. Akenes hardly margined, beak slender, straight or slightly curved. On hillsides or in woods or prairies.

5. R. septentrionalis Poir. MARSH BUTTERCUP. Stems smooth or slightly hairy, erect, or in wet ground often forming long runners. Leaves 3-divided, on long petioles, the divisions stalked, cleft or lobed, and wedge-shaped. Petals yellow, obovate, twice as long as the sepals. Akenes flat, strongly margined, beak stout and nearly straight. In moist soil.

6. R. hispidus Michx. RECLINING BUTTERCUP. Perennial. Stems ascending or spreading, densely soft-hairy when young, few-leaved. Leaves pinnately 3–5-divided, with sharply cleft divisions. Flowers $\frac{1}{2}$–$1\frac{1}{2}$ in. in diameter. Petals about twice as long as the spreading sepals. Head of fruit globose or nearly so. Akenes broadly oval, lens-shaped, with a narrow margin. In dry woods and thickets.

7. R. pennsylvanicus L. f. UPRIGHT BUTTERCUP. Perennial. Stems rough-hairy, erect, 2–3 ft. high. Leaves compound in threes, on long and very hairy petioles; leaflets long-stalked, 3-parted, the divisions sharply lobed or toothed. Flowers small. Petals yellow, shorter than the sepals. Akenes flat, smooth, in oblong heads; beak broad and straight. On low ground.*

8. R. bulbosus L. BULBOUS BUTTERCUP, EARLY BUTTERCUP. Stem upright, from a solid bulb about as large as a filbert, about 1 ft. high, hairy. Basal leaves 3-divided, the divisions lobed and cleft. Peduncles furrowed. Flowers large and showy ($\frac{1}{2}$–1 in. in diameter). Sepals strongly reflexed. Petals roundish, wedge-shaped at the base. Akenes with a very short beak. Naturalized from Europe. Common in grass fields in New England.

9. R. acris L. TALL BUTTERCUP. Erect, hairy, 2–3 ft. high. Leaves 3–7-parted, the divisions of the lower ones wedge-shaped, deeply cut and lobed. Peduncles not furrowed. Sepals spreading, downy. Petals obovate, a little smaller and paler yellow than in No. 8. A common weed, naturalized from Europe, in grass fields and elsewhere, especially eastward.

II. THALICTRUM L.

Erect perennial herbs. Leaves compound, with stipules. Flowers in panicles or racemes, often somewhat monœcious or diœcious, wind-fertilized. Sepals 4–5, petal-like. Petals none. Stamens many. Carpels few or many; ovule 1. Fruit a small head of akenes. [The following species are both usually diœcious.]

1. T. dioicum L. EARLY MEADOW RUE. Plant 1–2 ft. high, smooth and pale or with a bloom. Leaves all petioled, most of them thrice compound in threes; leaflets thin and delicate, roundish, 3–7-lobed. Flowers in slender panicles, purplish or greenish; staminate ones with slender, thread-like filaments, from which hang the conspicuous yellowish anthers. Rocky woods and hillsides.

2. T. polygamum Muhl. TALL MEADOW RUE. Stems from fibrous roots, tall and coarse, nearly or quite smooth, 4–8 ft. tall. Leaves twice compound, those of the stem sessile, the others long-petioled; leaflets oval or oblong, often cordate, smooth or downy beneath, quite variable in size on the same plant. Flowers small, in large panicles. Sepals 4 or 5, white. Filaments club-shaped. Akenes short-stalked. Thickets and meadows E.

III. ANEMONELLA Spach. (SYNDESMON)

Small, perennial herbs. Leaves compound, smooth, the basal ones long-petioled, those of the stem sessile. Flowers in a terminal umbel, slender-pediceled. Sepals petal-like. Petals none. Pistils 4–15; stigmas sessile, truncate.*

1. A. thalictroides Spach. RUE ANEMONE. Stem slender, 6–10 in. high, from a cluster of tuberous roots. Basal leaves long-petioled, twice compound in threes; leaflets oval, heart-shaped, 3–5-lobed. Stem leaves 2–3 compound in threes, whorled, the long-stalked leaflets veiny, forming an involucre of 6–9 apparently simple leaves. Flowers 3–6 in an umbel, $\frac{1}{2}$–$\frac{3}{4}$ in. wide; sepals 6–10, white. In rich woods.*

IV. HEPATICA Hill

Involucre of 3 small, simple leaves, so close to the flower as to look like a calyx. Leaves all basal, 3-lobed, heart-shaped, thick, and evergreen, purplish-red beneath. Flowers single, on rather slender hairy scapes.

1. H. triloba Chaix. ROUND-LOBED HEPATICA. Lobes of the leaves obtuse or rounded; those of the involucre obtuse; sepals 6–12, varying from blue to white.

2. H. acutiloba DC. SHARP-LOBED HEPATICA. Closely similar to the former, except for the acute lobes of the leaves and tips of the involucre.

[Both species have many local names, such as Liverleaf, Liverwort, Noble Liverwort, Spring Beauty.]

V. ANEMONE L.

Perennial herbs, usually with basal leaves, and 2 or 3 opposite or whorled stem leaves, constituting an involucre some distance below the flower or flower cluster. Sepals few or numerous, colored and petal-like. Petals usually wanting. Akenes pointed, or with long, feathery tails.

1. A. patens L., var. **Wolfgangiana**. Pasque Flower. Low plants, 1 in.–1 ft. high, clothed with long, silky hairs. Leaves divided in threes. Flower single, large, showy, pale-purplish, borne on a peduncle developed before the leaves. Carpels many, with long, hairy styles, which in fruit form tails 2 in. long. Prairies and bluffs, N.W.

2. A. caroliniana Walt. Carolina Anemone. Stem simple, from a roundish tuber, slightly downy, 6–12 in. high, bearing a single flower about 1 in. broad. Basal leaves 2–3, long-petioled, compound in threes, the divisions cut or lobed; stem leaves sessile, compound in threes, the divisions wedge-shaped. Sepals 12–20, white; head of fruit becoming oblong; akenes woolly. In open woods W.*

3. A. cylindrica Gray. Long-Fruited Anemone. Plants about 2 ft. high, branching, with an involucre of long-petioled, divided, and cleft leaves, from within which spring several long, naked peduncles. Flowers greenish-white. Sepals obtuse. Head of fruit cylindrical, composed of very many densely woolly akenes. Dry woods and prairies.

4. A. virginiana L. Plant hairy, 2–3 ft. high. Peduncles 6–12 in. long, sometimes forking, the first ones naked, the later ones with a little 2-leaved involucre at the middle. Leaves of the involucre 3, each 3-parted, the divisions ovate-lanceolate, pointed. Sepals acute. Head of fruit ovoid. Woods and meadows.

5. A. canadensis L. Plant hairy, rather low. Peduncle arising from a 3-leaved primary involucre, then branching, each branch bearing at the middle a 2-leaved secondary involucre. Leaves of the primary involucre broadly wedge-shaped, 3-cleft, the divisions cut and toothed. Sepals obovate, white. Head of fruit spherical. In low ground or woods.

6. A. quinquefolia L. Wind Flower, Wood Anemone. Stem simple, from a thread-like rootstock; involucre of 3 leaves, each petioled, and of 3 leaflets, which are cut, toothed, or parted. Peduncle 1-flowered. Sepals 4–7, white, often tinged with purple outside. Carpels 15 or 20. This species is very nearly related to, but now regarded as distinct from, the European *A. nemorosa*.

VI. CLEMATIS L.

Perennial herbs or slightly woody vines, usually climbing by the leafstalks. Leaves opposite, simple or compound. Sepals 4, petal-like. Petals very small or wanting. Pistils numerous, tipped by the persistent styles, which often become long and plumose in fruit.*

1. **C. crispa** L. MARSH CLEMATIS. Stem climbing, a little woody below, slightly downy above, 3–5 ft. high. Leaves pinnately compound; leaflets 5–7, varying from lanceolate to ovate, thin, entire or 3–5-lobed. Flowers showy, perfect, solitary, on long axillary peduncles. Sepals lanceolate, taper-pointed, thick, wavy on the margins, twice the length of the stamens, light bluish-purple, 1–1½ in. in length. Tails of the ripened akenes 1 in. long, silky. Rich woods and river banks S.*

2. **C. Viorna** L. LEATHER FLOWER. Stem climbing, nearly smooth, 6–10 ft. long. Leaves usually pinnately compound, the lowest pair often compound in threes and the upper pair simple. Leaflets usually 5–7, oblong-ovate or oval, acute, firm, entire or lobed. Calyx bell-shaped, nodding; sepals ovate, taper-pointed with a short, recurved point, thick and leathery, reddish-purple, 1 in. long. Tails of the akenes plumose, 1½ in. long, brownish. On river banks and rich soil.*

VII. ISOPYRUM L.

Small, smooth herbs. Leaves 2–3 times compound, in threes; the leaflets 2–3-lobed. Flowers peduncled, white. Sepals 5, petal-like, soon falling. Petals wanting (in our species). Stamens 10–40. Pistils 3–6 or more.

1. **I. biternatum** T. & G. A delicate, erect plant, with alternate branches, looking much like *Anemonella*, with clustered stems from perennial tuberous roots. Damp woods.

VIII. CALTHA L.

Smooth perennials with large, roundish leaves. Sepals petal-like, 5–9. Petals none. Pistils 5–10, each consisting of a 1-celled ovary with a nearly sessile stigma. Fruit a many-seeded follicle.

1. **C. palustris** L. MARSH MARIGOLD, COWSLIPS, MEADOW BUTTERCUP (both the latter unsuitable names, but in common use). Stem hollow, smooth, ascending; leaves smooth, roundish and heart-shaped,

or kidney-shaped, with crenate, dentate, or nearly entire margins; the broad oval sepals bright yellow. Swamps or wet ground.

IX. PÆONIA L.

Perennial, from thick, fleshy roots; stems shrubby or herbaceous. Leaves much divided. Flowers terminal, large and showy. Sepals 5, leaf-like and persistent. Petals 5 or more. Pistils 3–5; ovaries surrounded by a disk.*

1. **P. officinalis** L. GARDEN PEONY. Herbaceous; flowering stems 1–2 ft. high. Leaves ample; leaflets lance-ovate, cut or incised, smooth. Flowers double, white or red. Follicles 2, erect, many-seeded. Common in gardens.*

X. COPTIS Salisb.

Low, smooth perennials, with 3-divided basal leaves. Flowers small, white, on scapes. Sepals 5–7, petal-like, soon falling. Petals 5–7, small, club-shaped, tubular at the apex. Stamens 15–25. Pistils 3–7, stalked. Pods thin and dry, 4–8-seeded.

1. **C. trifolia** Salisb. GOLD THREAD. A pretty, delicate plant, with slender, 1-flowered scapes, from long, bright-yellow, thread-like rootstocks, which are bitter and somewhat medicinal. Leaves later than the flowers, each of 3 wedge-shaped leaflets, which finally become shining and evergeen. Damp, cold woods and bogs.

XI. AQUILEGIA L.

Perennials, with leaves twice or thrice palmately compound, the divisions in threes.

Sepals 5, petal-like, all similar. Petals 5, all similar, each consisting of an expanded portion, prolonged backward into a hollow spur, the whole much longer than the calyx. Pistils 5, forming many-seeded pods.

1. **A. canadensis** L. WILD COLUMBINE. Flowers scarlet without, yellow within, nodding; spurs rather long.
2. **A. vulgaris** L. GARDEN COLUMBINE. Flowers often double, and white, blue, or purple. Spurs shorter and more hooked. Cultivated from Europe, and sometimes become wild.

XII. DELPHINIUM L.

Annual or perennial herbs. Stem erect, simple or branched. Leaves alternate, petioled, palmately divided. Flowers in

terminal racemes or panicles, showy. Sepals 5, colored, irregular, the upper one prolonged into a spur. Petals 4, unequal, the two upper ones with long spurs which are inclosed in the spur of the upper sepal, the other two short-stalked. Pistils 1–5; ovaries many-seeded.*

1. **D. tricorne** Michx. DWARF LARKSPUR. Perennial. Stem simple, from a tuberous root, usually low (½–1 ft. high), but sometimes 2 ft. high. Leaves deeply 5-parted, the divisions irregularly 3–5-cleft. Racemes few-flowered, loose. Flowers blue, sometimes white. Pods diverging. Southward.

2. **D. azureum** Michx. BLUE LARKSPUR. Perennial. Stem usually simple, slender, downy, 1–2 ft. high. Leaves 2–3 in. wide, 3–5-parted, the divisions cleft into 3–5 narrow, toothed, or entire lobes. Flowers in a strict, many-flowered, terminal raceme, showy, blue or whitish. Spur ascending, curved; lower petals bearded, 2-cleft. Pods erect. On rich or rocky soil in open places, N.*

XIII. ACONITUM L.

Erect, perennial herbs. Leaves alternate, palmately lobed or cut. Flowers irregular, in panicles or racemes. Sepals 5, the back one large, arched, and hooded, the front one the narrower. Petals 2–5, small, the 2 back ones clawed and covered by the hood of the sepals; 3 lateral ones small or wanting. Follicles 3–5. Seeds many, wrinkled.

1. **A. Napellus** L. MONKSHOOD. An erect, poisonous plant, 1–2 ft. high. Raceme simple and densely flowered. Flowers dark blue. Cultivated from Europe.

Several native species of *Aconitum* occur within our limits, but they are not common.

XIV. ACTÆA L.

Perennial. Stem simple. Leaves 2–3, compound in threes; leaflets ovate, sharply cut or toothed. Flowers white, in a short and thick terminal raceme. Sepals 4–5, soon deciduous. Petals 4–10, small. Pistil single; stigma 2-lobed. Fruit a many-seeded berry.*

1. **A. rubra** Willd. RED BANEBERRY. Stem about 2 ft. high. Raceme ovoid or hemispherical. Petals acute. Pedicels slender. Berries usually red, sometimes white, ovoid. Common N.

2. A. alba Miller. BANEBERRY. Stem erect, smooth or nearly so, 18–24 in. high. Leaves large and spreading; leaflets thin. Racemes very broad. Petals slender, truncate. Pedicels red, thickened in fruiting; berries white. In rich woods, more common S.*

34. BERBERIDACEÆ. BARBERRY FAMILY

Herbs or shrubs. Leaves alternate, simple or compound, usually without stipules. Sepals petal-like. Petals hypogynous, distinct, their number some multiple of 2, 3, or 4, never of 5. Stamens usually one opposite each petal; anthers commonly opening by 2 uplifted lids (the stamens of *Podophyllum* are exceptional). Pistil 1, 1-celled; ovules 2 or more. Fruit a berry or capsule.

I. PODOPHYLLUM L.

Perennial. Stem simple, smooth, erect, 12–15 in. tall, bearing 2 leaves with a large white flower between them. Sepals 6, falling off as the flower opens. Petals 6–9, obovate. Stamens twice as many as the petals; anthers splitting open lengthwise. Pistil 1; stigma large, flat, sessile. Fruit berry-like, 1-celled, many-seeded.*

1. P. peltatum L. MAY APPLE. Rootstock rather large. Leaves orbicular, shield-shaped, 5–9-lobed and toothed, smooth, 9–12 in. wide. Flowers 1–2 in. wide, on a peduncle 1–2 in. long. Stamens prominent; anthers opening longitudinally. Fruit 1½–2 in. long, oval, fragrant, edible; each seed surrounded by a pulpy covering. In rich woods. The roots and leaves are used in medicine.*

II. CAULOPHYLLUM Michx.

A perennial smooth herb, 1–2½ ft. high. Leaf large, single, sessile, thrice compound in threes, borne high up on the stem; there is also a large, very compound basal leaf. Flowers racemed or panicled, yellowish-green. Sepals 6, with 3 bractlets. Petals 6, gland-like, somewhat curved inward at the tip, much smaller than the sepals. Pistil 2-ovuled, the ovary soon bursting open and leaving the 2 blue seeds to ripen naked.

1. C. thalictroides Michx. BLUE COHOSH, PAPPOOSE ROOT. Whole plant purplish and covered with a bloom when young. Flowers appearing before the leaf is fully developed. Rich woods.

III. BERBERIS L.

Spiny shrubs with yellow wood. Leaves spinous-toothed, jointed on the very short petiole, often reduced to 3–7-cleft spines. Flowers in racemes, solitary or in pairs. Sepals 8–9, the outer minute. Petals 6, each with 2 nectar glands at the base. Stamens 6. Ovules few. Berry 1–2-seeded ; seeds bony-coated.

1. **B. vulgaris** L. COMMON BARBERRY. A shrub 4–6 ft. high. Leaves obovate, spinous-serrate; those on the old shoots mere spines. Flowers pale yellow, in drooping racemes. Stamens irritable, closing quickly toward the center of the flower when touched. Berry ½ in. long, nearly ellipsoidal in shape, scarlet or orange-scarlet, very acid, eatable when cooked. Cultivated from Europe and introduced in eastern New England and locally in the upper Mississippi Valley.

2. **B. Thunbergii** DC. A low shrub. Leaves entire, turning red and remaining so for a considerable time in autumn. Flowers solitary or in pairs. Berries bright red, remaining on the branches all winter. Cultivated from Japan.

35. MAGNOLIACEÆ. MAGNOLIA FAMILY

Trees or shrubs. Leaves alternate, not toothed or serrate. Flowers solitary, large and showy. Floral envelopes and stamens hypogynous. Calyx and corolla colored alike, the parts of the perianth forming 3 or more circles of 3 parts each. Stamens many. Carpels many, usually joined over the long receptacle and forming a sort of cone-shaped fruit, which may be either fleshy or dry.

I. MAGNOLIA L.

Aromatic trees or shrubs. Leaves alternate, often in clusters at the ends of the branches, entire, usually thick and leathery ; stipules large, quickly deciduous. Flowers terminal, showy, bisexual. Sepals 3, caducous. Petals 6–12, in 2–4 rows, concave. Stamens numerous. Ovaries numerous, 1-celled, 2-seeded, the mature follicles opening at the beak and the fleshy seeds remaining for some time suspended by slender threads.*

1. **M. virginiana** L. SWEET BAY. A small tree with light gray bark. Leaves scattered on the branches, evergreen, thick and leathery, oval or oblong, smooth and green above, white and with

a bloom, downy beneath, 4–6 in. long. Flowers white, fragrant, 2–3 in. in diameter; petals 9, concave. Cone 1½–2 in. long, pink. Common in swamps and along streams, New York and southward (a few in eastern Massachusetts). The leaves often used in flavoring soups, etc.

2. M. acuminata L. CUCUMBER TREE. A tree 60–90 ft. high. Leaves thin, oblong or oval, acute, light green and somewhat downy beneath, 5–10 in. long. Flowers oblong-bell-shaped, greenish-yellow, 2 in. long. Petals much longer than the sepals. Cone of fruit 2–3 in. long, often curved, cylindrical. Woods, especially S.

3. M. macrophylla Michx. LARGE-LEAVED UMBRELLA TREE. A small tree with gray bark. Leaves clustered at the ends of the branches, oblong or obovate, obtuse at the apex, cordate at the base, green and glabrous above, white and downy beneath, 1½–3 ft. long; petioles stout. Flowers white with a purple center, fragrant, 8–12 in. wide. Petals oblong, obtuse, two or three times as long as the sepals. Cone ovate, 4–6 in. long, bright red at maturity. Shady woods on light soil S.*

4. M. Fraseri Walt. EAR-LEAVED UMBRELLA TREE. A small tree with a slender trunk and widely spreading branches. Leaves clustered at the ends of the branches, deciduous, oblong or obovate, contracted, cordate and eared at the base, smooth on both sides, 8–12 in. long; petioles slender. Flowers white and fragrant, 6 in. broad. Petals longer than the sepals, spatulate or oblong, obtuse at the apex, narrowed at the base. Cone 3–4 in. long, pink at maturity. In rich woods S.*

II. LIRIODENDRON L.

A large tree with rough, dark-colored bark. Leaves scattered on the branches, deciduous, 3-lobed, truncate, stipuled, petioled. Flowers bisexual. Sepals 3, reflexed. Petals 6, erect. Stamens numerous. Ovaries numerous, 2-ovuled, joined over each other on the elongated receptacle, never opening, deciduous.*

1. L. tulipifera L. TULIP TREE. The largest tree in the family. Leaves roundish in outline, mostly 3-lobed, the terminal lobe truncate or broadly notched, usually heart-shaped at the base, smooth, green above, lighter beneath; petioles slender. Flowers terminal, bell-shaped, greenish-yellow marked with orange. Petals obovate, obtuse, about as long as the sepals. Mature cones ovate, acute, 2–3 in. long. Common on low ground, Pennsylvania and S. Often called "white wood," or, incorrectly, "white poplar." Wood valuable for making boxes and light furniture.*

36. CALYCANTHACEÆ. Calycanthus Family

Shrubs. Leaves opposite, entire, without stipules. Flowers solitary, often sweet-scented. Sepals and petals numerous, the outer sepals bract-like. Stamens many, short, the inner ones usually sterile. Ovaries several, inserted on the inside of an irregular, hollow, pear-shaped receptacle something like a large rose hip, forming 1-seeded akenes in fruit.

CALYCANTHUS L. (BUTNERIA)

Shrubs, 4–8 ft. tall; branches opposite. Leaves oval, downy beneath, short-petioled; both leaves and bark aromatic. Sepals and petals many, in several rows, somewhat fleshy, indistinguishable. Pistils several, inserted on the inner side of the persistent calyx tube. Mature fruit pear-shaped, dry, inclosing the akenes.*

1. **C. floridus** L. Sweet-Scented Shrub, Strawberry Bush, Spice Bush, Shrub. A widespreading bush, 4–8 ft. high; twigs downy. Leaves oval or oblong, acute or taper-pointed, rough above, downy beneath, 2–3 in. long. Flowers 1 in. wide, brownish-purple, very fragrant. Sepals united below to form a cup, on the inside of which the other parts of the flower are inserted; cup leafy-bracted on the outside. Banks of streams and rich hillsides S., often cultivated.*

37. ANNONACEÆ. Papaw Family

Trees or shrubs. Leaves alternate, entire, pinnately veined. Flowers bisexual, hypogynous, axillary, solitary. Calyx of 3 sepals; corolla of 6 thickish petals in 2 rows. Stamens many; filaments very short. Pistils several or many, becoming fleshy or pulpy in fruit.

ASIMINA Adans.

Shrubs or small trees. Leaves deciduous. Flowers nodding. Sepals 3, ovate. Petals 6, the 3 outer ones larger and spreading. Stamens very numerous, crowded on the globular receptacle. Ovaries 3–15, sessile, 1-celled, several-ovuled. Fruit a large, fleshy, oblong berry; seeds large, horizontal.*

1. A. triloba Dunal. Papaw. A small tree, 10–20 ft. high; bark nearly smooth, lead-colored. Leaves oblong-obovate, acute at the apex, obtuse at the base, rusty-downy when young and becoming smoother with age, 6–10 in. long. Flowers on branches of the previous season, appearing before or with the leaves; the short peduncles and the sepals brown-downy; petals purple, obovate, 3–4 times longer than the sepals. Fruit 3–5 in. long, edible when ripe. Common on banks of streams, especially S. and S.W. The bark is very tough and is often used in the place of rope.*

38. LAURACEÆ. Laurel Family

Aromatic plants, nearly always trees or shrubs. Leaves alternate, simple, usually entire, and marked with translucent dots. Calyx regular, hypogynous, of 4 or 6 colored sepals. Stamens in 3 or 4 circles of 3 each, the anthers opening by valves. Style single. Fruit a 1-seeded berry or drupe.

I. SASSAFRAS Nees.

A tree with rough, yellowish bark and a spreading top. Leaves deciduous, entire or 2–3-lobed. Flowers diœcious, involucrate, at the end of the twigs of the previous season. Calyx 6-parted, persistent in the pistillate flowers. Stamens 9, in 3 rows. Pistillate flowers with 4–6 abortive stamens and a single ovary. Fruit a drupe.*

1. S. variifolium Ktze. Sassafras. A tree, usually small and slender, but sometimes with a trunk 3 ft. in diameter and 125 ft. high. Leaves oval, entire, mitten-shaped or 3-lobed, downy when young but becoming smooth with age, dark green above, paler below, petiolate. Racemes several in a cluster, peduncled; flowers yellow. Stamens about as long as the sepals. Fruit dark blue, ovoid, on thickened red pedicels. All parts of the tree aromatic. Trees producing pistillate flowers rare. Common. The wood is valuable for cabinet making, and an aromatic oil is extracted from the bark.*

II. BENZOIN Fabric.

Shrubs. Leaves deciduous, entire. Flowers in lateral, sessile clusters, appearing before the leaves, diœcious or somewhat monœcious. Involucre of 4 scales. Stamens 9 in the staminate

flowers; filaments slender. Pistillate flowers with 12–15 abortive stamens and a single globose ovary with a short style.*

1. **B. æstivale** Nees. SPICE BUSH. A shrub, 5–15 ft. high, with smooth bark and slender twigs. Leaves oblong-obovate, acute at the base, pale and downy beneath, becoming smooth when old; petioles short. Flowers about as long as the pedicels, yellow, very fragrant. Ovary about as long as the style. Fruit an obovoid, red drupe, about $\frac{1}{3}$ in. long, on a slender pedicel. Banks of streams and damp woods. Twigs and leaves quite aromatic.*

39. PAPAVERACEÆ. POPPY FAMILY

Annual or perennial herbs, often with milky juice. Leaves sometimes all basal; stem leaves usually alternate without stipules. Flowers bisexual, regular or irregular. Sepals usually 2, shed as the flower opens. Petals 4–12, falling early. Stamens numerous or 6 (in 2 sets), 4, or 2. Carpels 2–16. Fruit a capsule.

I. ESCHSCHOLTZIA Cham.

Annual or perennial herbs. Leaves pale or bluish-green, usually cut into very narrow divisions. Sepals united into a pointed cap, which falls off in one piece as the flower opens. Petals 4, orange or yellow. Stamens many, with long anthers. Stigmas 2–6, spreading. Pods long and slender, grooved. Receptacle often surrounded by a rim on which the calyx rests.

1. **E. californica** Cham. Annual or perennial, with rather succulent leafy stems. Flowers large and showy, yellow or orange-yellow. Receptacle top-shaped, with a broad rim. Cultivated from California.

II. SANGUINARIA L.

Perennial. Rootstock thick, horizontal; joints and scars of previous growths persistent several years; juice orange-colored. Leaves on long petioles, kidney-shaped. Scape 1-flowered. Sepals 2, falling off as the flower opens. Petals 8–12. Ovary 1; stigmas 2. Capsule oblong, seeds crested.*

1. **S. canadensis** L. BLOODROOT. Leaves and scape with a bloom; leaves palmately 5–9-lobed, lobes rounded or toothed; scapes naked, nearly as long as the petioles. Flowers white, 1 in. or more wide.

Petals oblong or obovate, quickly deciduous. Capsule 1-celled, 2-valved, the valves separating from the persistent placentæ at maturity. In rich, open woods.*

III. CHELIDONIUM L.

Erect, branched, perennial herbs, with yellow juice. Leaves much divided. Flowers yellow. Sepals 2, falling as the flower opens. Petals 4. Ovary 1-celled; style dilated at the top, with 2 joined stigmas. Capsule linear.

1. C. majus L. CELANDINE. Stem 1–2 ft. high, brittle, slightly hairy, leafy. Leaves once or twice pinnate. Flowers small. A rather common weed in yards and along fences. Naturalized from Europe.

IV. PAPAVER L.

Annual or perennial herbs with milky juice. Stem erect, smooth, or rough-hairy, branching above. Leaves more or less lobed or dissected. Flower buds nodding, flowers showy. Sepals commonly 2, falling off as the flower opens. Petals 4–6. Stamens many. Stigma disk-like; ovules many, borne on many inwardly projecting placentæ.*

1. P. somniferum L. OPIUM POPPY. Annual. Stem erect, branched above, smooth and with a bloom, 2–3 ft. high. Leaves oblong, irregularly lobed or cut, sessile, clasping. Flowers nearly white, with a purple center, large and showy, on long peduncles. Capsule globose, seeds minutely pitted. About old gardens and waste places. Cultivated in southern Asia, where the juice of the capsules is dried to make opium.*

2. P. Rhœas L. CORN POPPY. Annual. Stem erect, hairy, 1–3 ft. high. Lower leaves petioled, upper ones sessile, all pinnately cut, the lobes serrate. Corolla scarlet, often with a dark center, 2–4 in. in diameter. Capsule smooth, obovoid. Waste ground, sometimes in fields. Introduced from Europe and often cultivated.

3. P. dubium L. SMOOTH-FRUITED POPPY. Annual. Stem slender, branching, 1–2 ft. tall. Leaves pinnatifid, the lower petioled, the upper sessile. Flowers large and showy, usually red; capsule long-obovoid, smooth. In cultivated ground. Both this and No. 1 are often cultivated in gardens and produce double flowers.*

4. P. orientale L. ORIENTAL POPPY. A large, rough-hairy perennial. Leaves large, deep green, almost pinnate. Flower very large, deep red. Cultivated from the eastern Mediterranean region.

5. P. nudicaule L. Iceland Poppy. A delicate but rough-hairy perennial plant. Leaves all basal, pale, pinnately cut. Flowers yellow-orange or white, borne singly on rather slender, hairy scapes. Cultivated from Europe.

V. ADLUMIA Raf.

A delicate climbing biennial. Leaves thrice-pinnate, cut-lobed. Sepals 2, very small. Petals 4, all united into a corolla which is slightly heart-shaped or 2-knobbed at the base, remaining as a spongy covering over the small, few-seeded pod.

1. A. fungosa Greene. Mountain Fringe, Allegheny Vine. Climbing several feet high by the leafstalks. Flowers pinkish-white. Rocky hillsides, often cultivated.

VI. DICENTRA Bernh. (BICUCULLA)

Smooth, delicate herbs, with watery juice. Leaves compound in threes and finely cut. Flowers racemed, nodding. Sepals 2, small and scale-like. Petals 4, slightly united to form a heart-shaped or 2-spurred corolla (Fig. 17), the inner pair spoon-

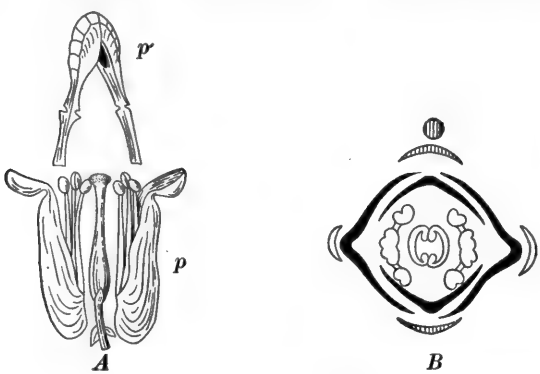


Fig. 17. Flower of *Dicentra*

A, view of flower partly dissected: *p*, the larger outer petals; *p′*, the spoon-shaped inner petals. *B*, floral diagram. (After Le Maout and Decaisne)

shaped, inclosing the stamens and pistil. Stamens 6; the filaments somewhat united into 2 sets, and the anthers in 2 sets close to the stigma. Stigma 2-crested. Pod 10–20-seeded.

1. D. Cucullaria Bernh. Dutchman's Breeches, Breeches Flower. A low, stemless perennial, with a delicate scape and a cluster of basal leaves with linear divisions, from a sort of bulb made of small, scaly grains. Flowers in a 4–10-flowered simple raceme, not fragrant. Spurs of the corolla longer than the pedicels; corolla mostly white with a yellowish tip. Rich woods, common.

2. D. canadensis Walp. Squirrel Corn, Wild Hyacinth. A low, stemless perennial, with scape and leaves much as in No. 1, and with small yellow tubers looking like grains of corn scattered along the underground shoots. Corolla only heart-shaped at the base, whitish or flesh-colored, very fragrant. Rich woods.

3. D. spectabilis Lem. Bleeding Heart, Ear Drops. Stems branching, recurved. Leaves large, twice compound in threes, the divisions rather broad, like those of the common peony. Racemes long, drooping, many-flowered. Flowers large, heart-shaped, bright pink. Cultivated from China.

VII. CORYDALIS Medic. (CAPNOIDES)

Leafy-stemmed biennial herbs (the American species). Leaves much divided, alternate or nearly opposite. Racemes terminal or opposite the leaves. Sepals 2, small. Petals 4; corolla with a single spur at the base, on the upper side. Capsule many-seeded.

1. C. sempervirens L. Pale Corydalis. Plant erect, covered with a bloom. Flowers pink-purple with yellow tips. Spur of the corolla very short and rounded. Rocky woods.

2. C. aurea Willd. Golden Corydalis. A low, spreading plant, finally ascending. Corolla bright yellow, 1–2 in. long; the spur shorter than the pedicel, somewhat bent. Shaded, rocky banks.

40. CRUCIFERÆ. Mustard Family

Herbs with pungent, watery juice, and alternate leaves without stipules. Sepals 4, often falling off early. Petals usually 4, arranged in the form of a cross. Stamens 6, the 2 outer ones shorter than the 4 inner ones. Fruit generally a pod, divided into 2 cells by a thin partition which stretches across from one to the other of the 2 placentæ. The flowers throughout the family are so much alike that the genera and species cannot usually be determined without examining the tolerably mature fruit.

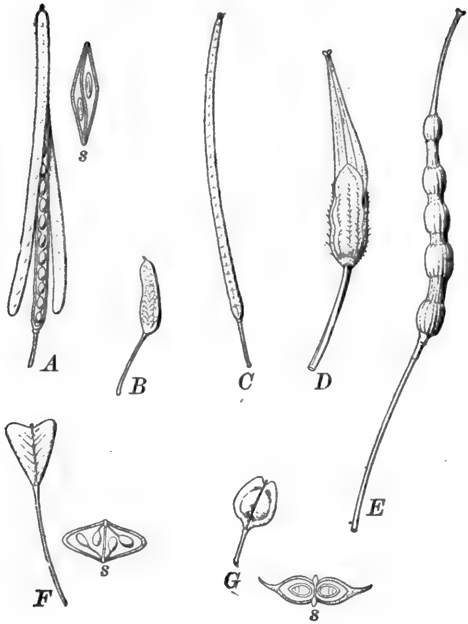


FIG. 18. Types of pods of *Cruciferæ*

A, flattened pod of *Arabis*, seeds in a single row in each cell: *s*, cross section of pod, showing flattening parallel to the partition. *B*, pod of *Radicula palustris*, seeds in several rows. *C*, nearly cylindrical pod of *Sisymbrium*. *D*, beaked pod of white mustard (*Sinapis alba*). *E*, dried necklace-shaped and beaked pod of radish (*Raphanus Raphanistrum*). *F*, flattened pod of shepherd's purse (*Capsella Bursa-pastoris*): *s*, cross section, showing flattening at right angles to the partition. *G*, flattened pod of *Lepidium campestre*; *s*, cross section, showing flattening at right angles to the partition. (The pods natural size, the sections somewhat magnified.) (After Cosson and De Saint-Pierre)

A

Pods short and flattened, contrary to the partition, splitting open when ripe.

Pod roundish. Lepidium, IV

Pod triangular, inversely heart-shaped. Capsella, V

B

Pods globular or cylindrical, splitting open when ripe.

(*a*) Pods globular. Flowers yellow. Lesquerella, III

(*b*) Pods cylindrical; seeds ellipsoid. Flowers very small, yellow. Sisymbrium, VIII

(*c*) Pods cylindrical; seeds globular. Flowers of moderate size, yellow. Brassica, VII

(*d*) Pods cylindrical; seeds in 2 rows; flowers white. Or pods ovoid or ellipsoid; flower yellowish. Aquatic plants, or growing in wet soil. Radicula, IX

(*e*) Pods cylindrical or angled; seeds in a single row, flattened. Flowers yellow. Barbarea, X

C

Pods elongated, often jointed, tapering toward the tip, never splitting open. Raphanus, VI

D

Pods flattened parallel to the partition, splitting open when ripe.

(*a*) Wild species; leafy-stemmed; growing in or near water. Pods linear. Cardamine, XII

(*b*) Wild species; stems naked below, bearing only 2 or 3 leaves. Pods lanceolate. Dentaria, XI

(*c*) Wild species; leafy-stemmed; growing on dry ground or rocks. Pods linear; seeds usually winged or margined. Arabis, XIII

(*d*) Cultivated species. Pods round or roundish. Lobularia, I

(*e*) Cultivated species; covered with a grayish down of star-shaped hairs. Pods cylindrical. Matthiola, II

I. LOBULARIA Desv. (KONIGA)

Perennial, though usually growing as an annual. Stems branching, diffuse; branches slender. Leaves small, entire, downy, with forked hairs. Flowers small, white, in numerous terminal racemes. Petals obovate, entire, twice as long as the sepals. Filaments enlarged below. Pod round, compressed; seeds 1 in each cell.*

1. L. maritima Desv. SWEET ALYSSUM. Stem weak, diffuse, ascending, minutely downy. Lower leaves narrowed into a petiole, the upper sessile. Racemes erect, many-flowered. Flowers fragrant, pedicels ascending. Pod often pointed. Common in cultivation and often run wild.*

II. MATTHIOLA R. Br.

Herbaceous or shrubby oriental plants, covered with a down composed of star-shaped hairs. Flowers in showy racemes of many colors, ranging from white to crimson. Stigmas large and spreading. Pods nearly cylindrical, except for a prominent midrib on each valve.

1. M. incana R. Br. COMMON STOCK, GILLYFLOWER. Biennial or perennial, with somewhat woody stems. Cultivated in greenhouses and gardens.

III. LESQUERELLA Wats.

Low herbs with stellate hairs. Leaves simple. Flowers in racemes, mostly yellow. Pod globular-inflated, with a translucent partition nerved from the apex to the middle. Seeds few, several or many, flattened, marginless or nearly so.

1. L. globosa Wats. Annual or biennial. Slender, somewhat branched, 6–20 in. high, covered with fine stellate hairs. Basal leaves 1–1½ in. long, oblong-obovate, obtuse. Stem leaves smaller, linear or oblong, sessile. Raceme finally elongated with thread-like diverging pedicels. Flowers light yellow. Style slender, much longer than the small globose pod. Rocky banks and open places S. and W.

2. L. argentea Pursh. SILVERY BLADDER POD. Biennial or perennial, 6–18 in. high, densely stellate-hairy. Leaves linear to oblanceolate, blunt, entire, the lower ones 2–3 in. long. Flowers yellow. Pods downy, on recurved pedicels. Plains W.

IV. LEPIDIUM L.

Annual. Stem erect, or sometimes diffuse. Leaves entire, toothed, or pinnately divided. Flowers in a terminal raceme, small, white. Petals short, sometimes wanting. Stamens 2, 4, or 6. Pod rounded or obcordate, flattened contrary to the partitions.*

1. L. virginicum L. PEPPERGRASS, BIRDS' PEPPER, TONGUE GRASS. Stem erect, smooth, much branched, 1–2 ft. high. Lower leaves obovate in outline, pinnately cut with dentate lobes; upper leaves lanceolate, dentate, slightly downy. Flowers on slender pedicels; petals present, sometimes reduced in the later flowers. Stamens 2. Pod round. A weed growing in waste places.*

2. L. campestre R. Br. FIELD CRESS. Annual or biennial. Stem erect, branching above, downy, 8–18 in. high. Basal leaves entire or

pinnately cut toward the base, obtuse; stem leaves oblong or lanceolate, entire or somewhat toothed, with an arrow-shaped clasping base. Flowers white or yellowish, on stout pedicels. Pods ovate, winged, slightly notched, tipped with a very small persistent style. Fields and waste ground, becoming a troublesome weed. Naturalized from Europe.

V. CAPSELLA Medic. (BURSA)

Annual. Stem erect, downy, with branched hairs. Racemes terminal, becoming elongated in fruit. Flowers small, white. Pod obcordate or triangular, flattened contrary to the partition, shorter than the spreading pedicels.*

1. **C. Bursa-pastoris** Medic. SHEPHERD'S PURSE. Root long and straight. Stem branching above, downy below, smooth above. Lower leaves forming a rosette at the base of the stem, irregularly lobed or pinnately cut; stem leaves lanceolate, clasping, toothed or entire. Sepals downy, about $\frac{1}{2}$ as long as the petals. Pod triangular, notched, or cordate at the apex. Seeds several in each cell. A common weed.*

VI. RAPHANUS L.

Annual or biennial herbs. Basal leaves lyrate. Flowers in long racemes, white or yellow, purple-veined. Sepals erect. Pods rather long, slender-beaked, not splitting open but sometimes breaking across into 1-seeded joints.

1. **R. Raphanistrum** L. WILD RADISH, JOINTED CHARLOCK. A stout, hairy annual, 1–2 ft. high. Leaves cut into remote segments, which are coarsely toothed or serrate; terminal segment largest. Flowers yellow, turning whitish or purplish. Pods necklace-shaped, and with a long beak. A common weed eastward. Naturalized from Europe.
2. **R. sativus** L. COMMON RADISH. Similar to No. 1, but with pink or white flowers. Root fleshy, conical or turnip-shaped. Pod fleshy, 2–3-seeded, the beak often longer than the seed-bearing portion. Cultivated from Asia and occasionally self-sown in cultivated ground.

VII. BRASSICA L.

Branching herbs. Leaves often pinnately cut. Flowers in racemes, rather large, yellow. Sepals spreading. Pods nearly cylindrical, sometimes tipped with a beak which does not open. Seeds globular.

1. **B. alba** Boiss. White Mustard. Stem 2–5 ft. high, with reflexed hairs. Upper leaves pinnately cut. Pods borne on spreading pedicels, bristly, with a sword-shaped, 1-seeded beak occupying more than half their length. Seeds pale. Cultivated from Europe and introduced to some extent.

2. **B. arvensis** Ktze. Charlock. Stem 1–2 ft. high; it and the leaves rough-hairy. Upper leaves rhombic, barely toothed. Flowers $\frac{1}{2}$–$\frac{3}{4}$ in. across, somewhat corymbed, bright yellow. Pods knotty, spreading, at least $\frac{1}{3}$ of each consisting of a 2-edged, 1-seeded beak. A showy, troublesome weed in grain fields. Naturalized from Europe.

3. **B. juncea** Cosson. Similar to the preceding, but nearly or quite smooth. Pedicels slender. Beak slender, conical, not containing a seed. Naturalized from Asia and becoming very abundant eastward.

4. **B. nigra** Koch. Black Mustard. Stem 3–6 ft. high, somewhat hairy. Lower leaves lyrate, with the terminal lobe much the longest; stem-leaves linear-lanceolate, entire or toothed, smooth. Pods awl-shaped, 4-angled, smooth, lying against the stem; seeds brownish, more biting than in No. 1. Cultivated from Europe and introduced.

VIII. SISYMBRIUM L.

Annual or biennial herbs. Radical leaves spreading; stem leaves alternate, often eared at the base. Flowers in loose racemes, usually yellow, often bracted. Pods generally narrowly linear, cylindrical, or 4–6-angled; seeds many, ellipsoid, not margined.

1. **S. officinale** Scop., var. **leiocarpum.** Hedge Mustard. Stems branching, stiff. Leaves runcinate-toothed or lobed. Flowers very small, pale yellow. Pods somewhat 6-sided, awl-shaped, smooth, closely pressed against the stem. An unsightly weed in waste ground. Naturalized from Europe.

2. **S. canescens** Nutt. Tansy Mustard. Stem 1–2 ft. high. Leaves twice pinnately cut, usually covered with grayish down. Flowers very small, yellowish. Pods oblong, club-shaped, 4-angled, borne on pedicels projecting almost horizontally from the stem, in long racemes. Common westward.

IX. RADICULA Hill. (RORIPA)

Annual or biennial, mostly aquatic plants. Stems erect or diffuse, often widely branching. Leaves simple, pinnately lobed. Flowers small, white or yellow. Sepals spreading.

Stamens 1–6. Pod short and broad or nearly linear; seeds numerous, in 2 rows in each cell.*

1. **R. Nasturtium-aquaticum** B. & R. WATERCRESS. Aquatic herbs. Stems smooth, diffuse, rooting at the joints. Leaves with 3–9 rounded, pinnate lobes, the terminal lobe much the largest. Racemes elongating in fruit. Petals white, twice the length of the sepals. Pods linear, $\frac{1}{2}$–$\frac{3}{4}$ in. long, on slender, spreading pedicels. In ditches and slow streams. Often used for salad.*

2. **R. sinuata Greene.** SPREADING YELLOW CRESS. Perennial. Stems low and spreading. Leaves oblong or lanceolate, pinnately cleft, the lobes obtuse. Flowers yellow, about $\frac{1}{6}$ in. in diameter. Pods linear oblong, $\frac{1}{3}$–$\frac{1}{2}$ in. long. River bottoms and moist ground W.

3. **R. palustris** Mœnch. YELLOW WATERCRESS. Annual or biennial. Stem erect, branched, slightly downy. Leaves irregularly lyrate, the lower petioled, the upper sessile. Flowers small; petals yellow. Pods linear, spreading, longer than the pedicels. In wet places.*

4. **R. Armoracia** Robinson. HORSE-RADISH. A coarse herb, with large leaves, from stout, long, cylindrical rootstocks filled with a very sharp, biting juice. Basal leaves long-petioled, linear-oblong, obtuse, regularly scalloped; stem-leaves sessile. Racemes in panicles. Pods obovoid, on long, slender pedicels; seeds seldom or never ripening. Probably from Europe; cultivated and often introduced in damp ground.

X. BARBAREA R. Br.

Mostly biennials, somewhat resembling *Radicula*. Flowers yellow. Pod elongated, linear, cylindrical, or somewhat 4-sided. Style short. Seeds in 1 row in each cell, not margined.

1. **B. vulgaris** R. Br. WINTER CRESS, YELLOW ROCKET. Smooth, with tufted stems 1–2 ft. high. Lower leaves petioled, pinnately cut, with 1–4 pairs of lateral divisions and a rounded, much longer terminal one; upper leaves nearly or quite sessile. Flowers $\frac{3}{8}$ in. in diameter or less. Pods erect or spreading. Fields and waste ground. Introduced from Europe into the eastern and central states.

XI. DENTARIA L.

Stems naked below, 2–3-leaved above, from a thickish, more or less knotted or interrupted rootstock. Flowers rather large, in early spring. Pod lance-linear, flattish; seeds in 1 row, wingless; seedstalks broad and flat.

1. D. diphylla L. Two-Leaved Toothwort, Pepper Root, Crinkle Root. Rootstock long, often branched, toothed, eatable, with a flavor like that of cress or radish. Stem leaves 2, close together, each composed of 3 ovate-diamond-shaped and toothed or crenate leaflets; the basal leaf like the stem leaves. Flowers white. Damp woods.

2. D. laciniata Muhl. Crow's-Foot. Rootstock short, necklace-like. Stem leaves 3-parted; basal leaf often absent. Flowers white or rose color. Woods.

XII. CARDAMINE L.

Annual or perennial. Rootstock often scaly or bulb-bearing. Stem erect or ascending, usually smooth. Leaves more or less divided. Flowers in terminal racemes, white or purple. Petals rather large. Stamens 6. Fruit a linear, flattened pod; seeds several, in a single row in each cell.*

1. C. rhomboidea DC. Bulbous Cress. Perennial. Root tuberous. Stem simple, erect, smooth, without runners, 9–18 in. tall. Lower leaves long-petioled, ovate, orbicular, or heart-shaped, often angled or toothed; the upper short-petioled or sessile, lanceolate or oblong, toothed or entire. Pedicels $\frac{1}{2}$–1 in. long. Petals white, $\frac{1}{4}$–$\frac{1}{3}$ in. long. Pod erect, linear-lanceolate, tipped by the persistent style; seeds round-oval. Cool, wet places.*

2. C. pennsylvanica Muhl. Bitter Cress. Annual. Stem slender, erect, simple, or with a few slender branches, 6–15 in. tall. Leaves mostly in a cluster at the base of the stem, pinnately divided, the terminal lobe roundish, the lateral lobes narrower, somewhat hairy above; stem leaves nearly linear. Flowers small. Petals white, longer than the sepals. Stamens 4. Pods linear, erect on erect pedicels, about 1 in. long; seeds oval. In wet places.*

XIII. ARABIS L.

Annual or perennial herbs, smooth, or with forked or star-shaped hairs. Basal leaves spatulate; stem leaves sessile. Flowers usually white. Petals entire, usually with claws. Pods linear, flattened; seeds often margined or winged.

1. A. hirsuta Scop. A rough-hairy, erect, leafy-stemmed biennial, 1–2 ft. high. Leaves simple; stem leaves oblong or lanceolate, entire or toothed, somewhat clasping, often with an arrow-shaped base. Flowers small, greenish-white, the petals somewhat longer than the sepals. Pods and pedicels upright. Style almost wanting. Seeds roundish, somewhat wing-margined. Rocks, N.

2. A. lævigata Poir. A smooth, leafy-stemmed biennial, 1–2 ft. high, covered with a bloom. Stem leaves lance-linear, clasping. Flowers small and whitish, the petals hardly longer than the sepals. Pods 2–3 in. long, flattened, spreading, and recurved; seeds broadly winged. Rocks.

3. A. canadensis L. SICKLE POD. An upright, leafy-stemmed biennial, 2–3 ft. high, simple or slightly branching above, sometimes slightly hairy at the base. Stem leaves sessile, oblong-lanceolate, pointed at both ends, downy; the lower ones toothed. Flowers small, whitish, the petals twice as long as the sepals. Pods scythe-shaped, much flattened, hanging from hairy pedicels; seeds broadly winged. Rocky hillsides.

41. CAPPARIDACEÆ. CAPER FAMILY

Herbs (when growing in cool temperate regions), with bitter or nauseous juice. Leaves alternate, usually palmately compound. Flowers often not actinomorphic, usually bisexual. Sepals 4–8. Petals 4 or wanting. Stamens 6 or more. Ovary and pod 1-celled, with 2 rows of ovules; seeds kidney-shaped.

I. POLANISIA Raf.

Ill-smelling annual plants covered with glandular or clammy hairs. Sepals distinct, spreading. Petals with claws, notched at the tip. Stamens 8–32, of various lengths. Receptacle not lengthened. Pod linear or oblong, rather large, many-seeded.

1. P. graveolens Raf. A very strong-scented, leafy, branching herb, 6–15 in. high. Leaves with 3 oblong leaflets. Flowers small, pinkish and yellowish-white, in the axils of leafy bracts, in terminal racemes. Stamens 8–12, not much longer than the petals. Pod about 2 in. long, slightly stalked. Gravelly banks.

II. CLEOME L.

Mostly annual herbs. Stems branched. Leaves petioled, simple, or with 3–7 entire or serrate leaflets. Flowers in bracted racemes. Sepals 4, often persistent. Petals 4, often long-clawed, nearly equal, entire. Stamens 6, filaments thread-like, usually projecting much, but sometimes 1–3 much shorter than the others, inserted on the short receptacle. Ovary on a

short stalk with a small gland at its base. Fruit a slender capsule on an elongated stalk.*

1. **C. serrulata** Pursh. Rocky Mountain Bee Plant, Stinking Clover. A smooth plant 2 ft. or more high. Leaves with 3 leaflets. Flowers pink, showy, in leafy-bracted racemes. Pod oblong to linear, 1–2 in. long. Cultivated as an ornamental plant and also for bees Common in a wild condition W.

42. RESEDACEÆ. Mignonette Family

Annual or perennial herbs, rarely shrubs. Leaves alternate, simple or pinnately cut. Flowers racemed or spiked, bracted. Calyx 4–7-parted, often not actinomorphic. Petals 4–7, hypogynous, often unequal and cleft or notched. Stamens usually many, borne on a large one-sided hypogynous disk. Ovary of 2–6 carpels, which are more or less united into a single 1-celled, many-seeded, several-lobed or -horned pistil, which opens at the top before the seeds ripen.

RESEDA L.

Annual. Stems diffuse, widely branched. Leaves sessile, entire or lobed, smooth. Flowers in close racemes or spikes. Petals 4–7, toothed or cleft. Stamens 8–30, inserted at one side of the flower. Capsule 3–6-lobed.*

1. **R. odorata** L. Mignonette. Stem widely diffuse, 6–12 in. high, smooth. Leaves wedge-shaped, entire or 3-lobed. Flowers small, greenish-yellow, very fragrant. Petals deeply 7–13-cleft. Often cultivated. From Egypt.*

43. SARRACENIACEÆ. Pitcher Plant Family

Perennial, apparently stemless, marsh herbs. Leaves tubular or trumpet-shaped. Flowers single, nodding, on a naked or bracted scape. Sepals 4–5, colored, persistent. Petals 5, deciduous, or sometimes wanting. Stamens numerous. Pistil compound, 5-celled, many-ovuled; style terminal, nearly as broad as the flower, shield-shaped.*

SARRACENIA L.

Rootstock short, horizontal; scape naked. Leaves trumpet-shaped, with a wing extending nearly to the base and a broad blade at the apex; tube hairy within, with downward-pointing, stiff hairs. Calyx 3-bracted. Petals obovate, drooping or incurved. Style umbrella-shaped, 5-angled; stigmas at the hooked angles of the style on the under surface. Capsule globose, rough. [The tubular leaves usually contain more or less water and dead insects, the latter having been attracted by a honey-like secretion near the opening.]

1. **S. purpurea** L. SIDESADDLE FLOWER. Leaves ascending, curved, broadly winged, purple-veined, 4–8 in. long; blade erect, round-cordate, hairy on the inner side. Scapes 12–18 in. tall; flower deep purple, about 2 in. broad; style yellowish. Mossy swamps.*

44. SAXIFRAGACEÆ. SAXIFRAGE FAMILY

Herbs or shrubs. Leaves alternate or opposite, generally without stipules. Sepals 4 or 5, more or less joined with each other and not usually hypogynous. Petals as many as the sepals and alternate with them. Stamens as many as the petals and alternate with them, or 2–10 times as many. Ovary usually of two carpels, united only at the base or more or less throughout. Fruit generally a 1–2-celled capsule, sometimes a berry; seeds many, with endosperm.

I. SAXIFRAGA L.

Herbs with simple or palmately cut leaves and generally cymose or panicled flowers. Sepals 5, more or less united. Petals 5, entire, inserted on the calyx tube. Stamens 10. Capsule consisting of 2 (sometimes more) ovaries, united at the base, separate and diverging above.

1. **S. pennsylvanica** L. SWAMP SAXIFRAGE. Perennial. Leaves 4–8 in. long, oblong-lanceolate and tapering to the base, slightly toothed. Scape 1–2 ft. high, bearing an oblong cluster of small greenish flowers, at length diffusely panicled. Petals greenish-yellow

(rarely crimson), linear-lanceolate, hardly longer than the calyx lobes. Boggy ground.

2. S. virginiensis Michx. EARLY SAXIFRAGE, MAYFLOWER. Perennial. Apparently stemless, with a cluster of spatulate, obovate, or wedge-shaped basal leaves, and a scape 3–9 in. high, which bears a dense cluster of small white flowers, becoming at length a panicled cyme. Petals white, oblong, much longer than the calyx. Rocks and dry hillsides N.

II. TIARELLA L.

Perennial. Flowers white, in racemes. Calyx white, 5-parted, nearly hypogynous. Corolla of 5 very narrow petals, with slender claws, alternating with the calyx lobes. Stamens 10, springing from the calyx tube and extending outside the flower. Styles 2, long and slender; ovary 1-celled, 2-beaked. In fruit one of the carpels grows to be much larger than the other, thus making up the main bulk of the thin, dry pod, which has a few seeds attached near the bottom.

1. T. cordifolia L. FALSE MITERWORT. Stem 5–12 in. high, usually leafless, sometimes with 1 or 2 leaves. Rootstock bearing runners in summer. Leaves heart-shaped, sharply lobed, the lobes with acute or mucronate teeth, somewhat hairy above, downy beneath. Raceme short and simple. Rocky woods, especially N.

III. HEUCHERA L.

Perennials, with a tall scape and roundish, heart-shaped basal leaves. Flowers rather small, greenish or purplish, in a long panicle. Calyx 5-cleft, the tube somewhat perigynous. Petals 5, small, spatulate, inserted with the 5 stamens on the margin of the calyx tube. Capsule 1-celled, 2-beaked, splitting open between the beaks.

1. H. americana L. COMMON ALUM ROOT. Scapes 2–4 ft. high, rather slender, often several from the same root, hairy and glandular. Basal leaves large and long-petioled, abundant, somewhat 7-lobed. Flowers whitish with a tinge of purple, in a loose panicle. Stamens projecting considerably outside the flower, their anthers of a bright terra cotta color. The root is very astringent and is somewhat used as a home remedy. Shaded banks, fence rows, and thickets; common W.

IV. MITELLA L.

Delicate perennial herbs. Flowers small, pretty, in a simple raceme or spike. Calyx 5-cleft, slightly perigynous. Petals 5, cut-fringed, inserted on the throat of the calyx tube. Stamens 5 or 10, not projecting from the calyx tube. Styles 2, very short. Ovary and pod 2-beaked, globular, 1-celled.

1. **M. diphylla** L. TWO-LEAVED BISHOP'S CAP, FRINGE CUP, FAIRY CUP. Stemless, with long-petioled, roundish-cordate root leaves, and a scape about 1 ft. high, bearing 2 opposite, nearly sessile leaves. Flowers many, racemed, white. Woods.

V. PHILADELPHUS L.

Shrubs. Leaves simple, opposite, 3–5-ribbed, petioled, without stipules. Flowers solitary or in cymes, large, white. Calyx tube top-shaped, the epigynous limb 4–5-parted, persistent. Petals 4–5, rounded or obovate. Stamens 20–40, shorter than the petals. Ovary 3–5-celled, many-seeded; styles 3–5, more or less united.*

1. **P. grandiflorus** Willd. LARGE-FLOWERED SYRINGA. Shrub, 6–10 ft. high; branches downy. Leaves ovate or ovate-oblong, taper-pointed, sharply serrate, downy, 3-ribbed. Flowers solitary or 2–3 together, white, $1\frac{1}{2}$–2 in. broad, not fragrant. Calyx lobes ovate, taper-pointed, about twice as long as the tube. On low ground S., and cultivated.*

2. **P. coronarius** L. GARDEN SYRINGA. Shrub, 8–10 ft. high. Leaves oval or ovate, obtuse at the base, acute at the apex, remotely toothed, smooth above, downy beneath. Flowers in terminal racemes, creamy white, 1–$1\frac{1}{2}$ in. wide, very fragrant. Calyx lobes ovate, acute, longer than the tube. Common in cultivation. From southern Europe.*

VI. DEUTZIA Thunb.

Shrubs with simple, opposite leaves, without stipules. Flowers all bisexual and alike, racemed or panicled, showy. Calyx lobes 5. Petals 5. Stamens 10, 5 long and 5 short; filaments flat and 3-pronged, the middle prong bearing an anther. Styles 3–5, slender. Pod 3–5-celled.

1. **D. gracilis** Sieb. & Zucc. About 2 ft. high, loosely spreading. Leaves ovate-lanceolate, sharply serrate, smooth. Flowers white, very numerous. Cultivated from Japan, often in greenhouses.

VII. RIBES L.

Shrubs. Leaves palmately veined and lobed, sometimes with stipules. Calyx tube egg-shaped, its 5 epigynous lobes usually colored like the petals. Petals 5, small, generally inserted on the throat of the calyx tube. Stamens 5, inserted with the petals. Styles 2; ovary 1-celled, with 2 placentæ on its walls, becoming in fruit a pulpy (usually eatable) berry.

1. **R. Cynosbati** L. PRICKLY WILD GOOSEBERRY. Spines in pairs. Leaves long-petioled, downy, heart-shaped, cut-dentate. The single style and the stamens not projecting from the calyx tube. Berries generally prickly, brownish-purple, pleasant-flavored.

2. **R. gracile** Michx. SLENDER GOOSEBERRY. Spines slender, solitary, or in pairs or threes. Leaves with slender petioles, somewhat downy when young, round, the base truncate or obtuse, 3–5-lobed, the divisions obtuse and toothed. Flowers often in threes, white or greenish, drooping. Calyx lobes longer than the tube; stamens decidedly projecting from the tube. Berries smooth, reddish-purple. Dry or rocky soil W.

3. **R. rotundifolium** Michx. SMOOTH WILD GOOSEBERRY. Spines few and short, prickles few or absent. Leaves roundish, lobed, with the lobes crenate-dentate, often downy. Peduncles slender; flowers inconspicuous. Calyx lobes reflexed. Styles and stamens projecting decidedly from the calyx tube. Berries smooth.

4. **R. oxyacanthoides** L. NORTHERN GOOSEBERRY. Spines usually solitary, often numerous. Leaves petioled, their lower surfaces and petioles commonly downy. Flowers 1–3 together, on short pedicels, greenish-purple or white. Berry $\frac{1}{3}$–$\frac{1}{2}$ in. in diameter, smooth, reddish-purple. Low grounds and damp woods N.

5. **R. americanum** Mill. WILD BLACK CURRANT. Branches thornless, erect. Leaves resinous-dotted, somewhat heart-shaped, 3–5-lobed, toothed. Flowers large, whitish. Calyx tubular-bell-shaped, smooth. Fruit round-ovoid, black, smooth. In woods.

6. **R. vulgare** Lam. RED CURRANT. Stems more or less reclining. Leaves somewhat heart-shaped, obtusely 3–5-lobed. Racemes drooping. Limb of the calyx wheel-shaped. Berries acid, eatable, red or light amber-colored. Cultivated from Europe; also somewhat naturalized.

7. **R. odoratum** Wendland. GOLDEN CURRANT, FLOWERING C., MISSOURI C., CLOVE CURRANT. A much taller shrub than the common red currant. Leaves 3-lobed, toothed. Racemes short and loose. Tube of the yellow calyx much longer than its limb. Flowers very fragrant. Fruit brownish-black, barely eatable.

45. PLATANACEÆ. Sycamore Family

Trees, with simple, alternate, petioled leaves, with stipules; the bases of the petioles covering the buds. Flowers monœcious, in axillary, long-peduncled, globose heads. Calyx and corolla very inconspicuous, each consisting of 3–8 minute scales, or wanting. Stamens as many as the sepals and opposite them. Pistils several, inversely conical, hairy at the base; styles long. Capsules 1-seeded.*

PLATANUS L.

Characters of the family.

1. P. occidentalis L. Sycamore, Buttonwood. A large tree, bark light-colored, smooth, peeling off in large, thin plates. Leaves large, round-heart-shaped, angularly lobed and toothed, densely white-woolly when young, becoming smooth with age; stipules large, toothed. Fruit in a globular, drooping head, which remains on the tree through the winter, dropping the seeds very slowly. Common on river banks and in swampy woods.*

46. ROSACEÆ. Rose Family

Herbs, shrubs, or trees. Leaves alternate or rarely opposite, simple or compound, with stipules. Calyx 5-lobed. Petals 5, rarely wanting, inserted with the stamens on the edge of a disk that lines the calyx tube. Stamens many, rarely 1 or few. Carpels 1 or more, distinct or united, superior or inferior. Fruit a pome, a drupe or group of drupes, or 1–several akenes or follicles, rarely a berry or capsule. The relation of the parts of the flower to each other and to the receptacle is shown in Fig. 19.

dry dehiscent more than 1 carpel.

A

Ripe carpels not inclosed within the calyx tube.

1. Fruit dry.
   - (*a*) Carpels 1–5, inflated. — Physocarpus, I
   - (*b*) Pods 5–8, not inflated, 2–several-seeded. — Spiræa, II

(c) Carpels 5–15 (usually 10), 1-seeded. Filipendula, X

(d) Akenes 2–6, styles not lengthening after flowering. Waldsteinia, VIII

(e) Akenes many, on a dry receptacle. Styles not lengthening. Potentilla, IX

(f) Akenes many, on a dry receptacle. Styles lengthening after flowering, forming tails to the akenes. Geum., XI

2. Fruit fleshy.

(a) Akenes several–many, becoming little drupes. Rubus, XII

(b) Akenes many, dry on ripening, on a fleshy, eatable receptacle. Fragaria, VII

(c) Pistil solitary, becoming a drupe Prunus, XIV

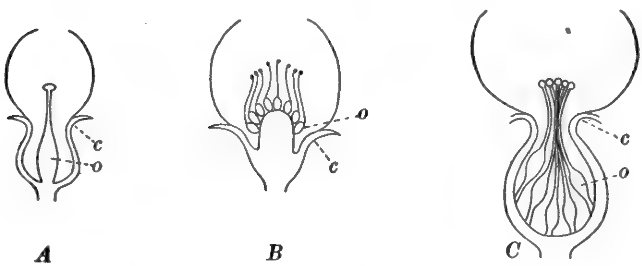


FIG. 19. Pistils in the Rose Family

A, *Prunus*-type; *B*, *Potentilla*-type; *C*, *Rosa*-type. *c*, calyx; *o*, ovary

B

Ripe carpels inclosed within the calyx tube.

1. Fruit a pome.

(a) Carpels more than 2-seeded; seeds covered with a mucilaginous pulp. Fruit 5-celled. Cydonia, III

(b) Carpels 2-seeded (except in some cultivated varieties); seeds without pulp. Fruit 5-celled. Pyrus, IV

(c) Carpels 2-seeded; fruit 10-celled. Amelanchier, V

2. Fruit not evidently a pome, or not at all so.
   (*a*) Trees or shrubs. Fruit with a stone usually of 2–5 bony 1-seeded carpels united. Cratægus, VI
   (*b*) Shrubs. Fruit with many akenes borne on the interior of a fleshy calyx tube. Rosa, XIII

I. PHYSOCARPUS Maxim. (OPULASTER)

Shrubs. Leaves simple, palmately veined and lobed, petioled. Flowers white, in terminal corymbs. Calyx spreading, 5-lobed. Petals 5. Stamens numerous. Pistils 1–5, short-stalked; stigma terminal; ovaries becoming inflated at maturity, 2–4-seeded, splitting open.*

1. P. opulifolius Maxim. NINE-BARK. A spreading shrub, 3–6 ft. high, the old bark separating into thin strips. Leaves petioled, broadly ovate or rounded, often heart-shaped, 3-lobed, the lobes doubly crenate-serrate; stipules deciduous. Corymbs terminal, peduncled, nearly globose, downy, many-flowered. Follicles 3–5, much longer than the calyx, smooth and shining, obliquely tipped by the persistent style. Banks of streams.*

II. SPIRÆA L.

Shrubs with simple leaves. Flowers perfect, in terminal or axillary racemes or panicles. Calyx 5-cleft, persistent. Petals 5. Stamens numerous. Pistils usually 5, free from the calyx and alternate with its lobes. Follicles not inflated, 2–several-seeded.*

1. S. salicifolia L. WILLOW-LEAVED SPIRÆA. Shrubs 2–5 ft. high, branches smooth. Leaves lanceolate to oblong-ovate, smooth or nearly so, sharply serrate, base usually wedge-shaped, pale beneath; stipules deciduous. Flowers white or pink, panicle dense-flowered; follicles smooth. On low ground.*

2. S. cantoniensis Lour. BRIDAL WREATH. Shrubs 2–4 ft. tall; branches long, slender, and spreading. Leaves lanceolate, serrate, sometimes 3-lobed or pinnatifid, with a bloom beneath. Flowers white or pinkish, in axillary racemes or corymbs, often forming long wreaths. Follicles smooth. Cultivated from Europe.

3. S. tomentosa L. HARDHACK. Erect shrubs. Stems densely downy, usually simple. Leaves simple, ovate or oblong, serrate, densely rusty-downy below, smooth and dark green above. Flowers

small, pink or purple, in a close panicle. Follicles 5, densely downy, several-seeded. On low ground S., and along fence rows and in pastures N., where it is a troublesome weed.*

III. CYDONIA L.

Trees or shrubs. Leaves simple, toothed or lobed, stipules deciduous. Flowers usually solitary, white or pink. Calyx tube urn-shaped, 5-lobed, its epigynous lobes acute, spreading, persistent. Petals 5. Stamens numerous, inserted with the petals on the calyx tube. Styles 2–5, mostly 5, united at the base; ovary 5-celled, seeds many in each cell. Fruit a pome, globose, usually depressed or hollowed at the extremities; flesh without hard grains.*

1. C. vulgaris Pers. QUINCE. Shrub 6–12 ft. high. Leaves oblong-ovate, acute at the apex, obtuse at the base, entire, downy below. Flowers large, white or pink. Fruit ovoid, downy. Cultivated.*

2. C. japonica Pers. JAPAN QUINCE. A widely branching shrub, 3–6 ft. high; branches with numerous straight spines. Leaves ovate-lanceolate, acute at each end, smooth and shining, serrulate; stipules conspicuous, kidney-shaped. Flowers in nearly sessile axillary clusters, bright scarlet. Fruit globose. Common in cultivation.*

IV. PYRUS L.

Trees. Leaves simple, stipules small, deciduous. Flowers in cymes, large, white or pink. Calyx urn-shaped, 5-cleft, its epigynous lobes acute. Petals rounded, short-clawed. Stamens numerous, borne with the petals on the calyx tube. Styles 5, distinct or slightly united at the base. Fruit a pome, with about 2 seeds in each carpel.*

B. Fl. species 2–5 (*Malus*); species 6 (*Aronia*); species 7, 8 (*Sorbus*).

1. P. communis L. PEAR. A tree, often very large; head usually pyramidal, branches often thorny. Leaves thick and leathery, ovate or oval, acute, finely serrate or entire, downy when young, becoming smooth with age; petioles slender. Cymes few–several-flowered, terminal, and at the ends of "fruit spurs" grown the previous season. Flowers white. Styles not united. Fruit obovoid, with hard gritty grains near the core. A European and Asiatic tree common in cultivation.*

2. P. angustifolia Ait. NARROW-LEAVED CRAB APPLE. A small tree, with smooth, light gray bark. Leaves lanceolate or oblong, serrate, downy when young, acute at the base, short-petioled. Corymbs few-flowered. Flowers pink, fragrant, about 1 in. broad. Styles smooth, distinct. Fruit nearly globose, about $\frac{3}{4}$ in. in diameter, very sour. In open woods, Pennsylvania, West, and South.*

3. P. coronaria L. AMERICAN CRAB APPLE. A small tree, with smooth bark. Leaves triangular or oval-lanceolate, acutish or rounded or a little heart-shaped at the base, cut-serrate and often somewhat 3-lobed, slender-petioled, soon smooth. Flowers large, few in a cluster, pale rose color, very sweet-scented. Fruit bright green, turning yellowish, sometimes $1\frac{1}{2}$ in. in diameter, flattened at right angles to the pedicels, very fragrant. Glades, western New York, West, and South.

4. P. ioensis Bailey. WESTERN CRAB APPLE. A small tree, much like *P. coronaria* but with the leaves white-downy beneath, ovate-lanceolate and narrowed at the base. Fruit dull green with light dots, about 1 in. in diameter. Thickets W.

5. P. Malus L. APPLE. A tree with a rounded top and dark-colored bark. Leaves oval or ovate, obtuse or pointed, dentate or nearly entire, rounded at the base, smooth above, downy beneath. Cymes few–many-flowered. Flowers large, white or pink. Calyx downy. Fruit depressed-globose to ovoid, hollowed at the base and usually at the apex. Cultivated from Europe and often running wild in old pastures, etc., E.*

6. P. arbutifolia L. f. CHOKEBERRY, CHOKE PEAR, DOGBERRY. A shrub, 5–8 ft. high. Leaves oblong or oblanceolate, finely serrate, downy beneath, short-petioled. Flowers in a downy compound cyme, small, white or reddish. Fruit pear-shaped or nearly globular, not larger than a currant, very dark purple, dry and puckery. There is also a smooth-leaved variety with black fruit. Swamps and damp thickets, especially N.E.

7. P. americana DC. AMERICAN MOUNTAIN ASH. A tall shrub or small tree. Leaves odd-pinnate. Leaflets oblong-lanceolate, taper-pointed, sharply serrate, smooth, bright green. Flowers small, white, in large flat, compound cymes. Fruit bright scarlet, not larger than currants. Common N. and often cultivated.

8. P. Aucuparia Ehrh. EUROPEAN MOUNTAIN ASH OR ROWAN TREE. Larger than No. 7. Leaflets paler, downy beneath. Fruit larger, about $\frac{1}{2}$ in. in diameter. Cultivated from Europe.

V. AMELANCHIER Medic.

Shrubs or small trees, with smooth gray bark. Leaves simple, sharply serrate, petioled. Flowers white, in racemes.

Calyx tube 5-cleft, its lobes epigynous. Petals oblong. Styles 5, united below; ovary 5-celled, 2 ovules in each cell, often only 1 maturing. Fruit small, berry-like.*

1. **A. canadensis** Medic. SERVICE BERRY, JUNEBERRY, SHAD BUSH, SUGAR PLUM, SUGAR PEAR, WILD PEAR. A small tree, branches downy when young, soon becoming smooth. Leaves ovate to elliptical, finely and sharply serrate, acute at the apex, usually obtuse or cordate at the base. Racemes slender, many-flowered, appearing before or with the leaves. Flowers showy. Petals 4 or 5 times the length of the smooth calyx lobes. Fruit globose, dark red, edible. In rich woods. Extremely variable in height and in shape of leaves.*

2. **A. spicata** K. Koch. ROUND-LEAVED JUNEBERRY. Much like *A. canadensis*, but with the leaves broadly oval, ovate, or almost orbicular, and usually rounded at both ends. Woods and thickets, especially N.

VI. CRATÆGUS L.

Shrubs or small trees, mostly with numerous strong spines, wood very hard. Leaves serrate, lobed or deeply incised, petioled. Flowers white or pink, in terminal corymbs or sometimes solitary. Calyx tube urn-shaped, 5-cleft, the limb persistent. Petals round. Stamens few or many. Styles 1–5, distinct; ovules 1 in each cell. Fruit a small pome with bony carpels.* [The species are hard to distinguish and are not very perfectly defined. Probably more than 60 species occur within the limits of this flora.]

VII. FRAGARIA L.

Perennial scape-bearing herbs, with runners. Leaves with 3 leaflets; stipules united to the petiole. Flowers (of American species) white. Calyx hypogynous, 5-parted, 5-bracted, persistent. Petals 5. Stamens many. Carpels many, on a convex receptacle. Akenes of the ripe strawberry many, very small, more or less imbedded in the large, sweet, pulpy receptacle.

1. **F. virginiana** Duchesne. WILD STRAWBERRY. Leaflets thick, oval to obovate, coarsely serrate, somewhat hairy. Scape usually shorter than the petioles, few-flowered. Fruit ovoid, akenes imbedded in deep pits. Common.*

2. F. vesca L. European Strawberry. Leaflets ovate or broadly oval, dentate above, wedge-shaped below, slightly hairy. Scape usually longer than the petioles. Fruit globular or oval, akenes adherent to the nearly even surface of the receptacle. Common in cultivation. Many of the cultivated varieties of strawberry are hybrids between the two described above. The following variety is by some regarded as distinct.*

Var. **americana** Porter. American Wood Strawberry. Slender, smooth or silky-downy. Leaflets very thin, sharply cut-toothed, downy beneath with close-lying silvery hairs, the down of the scapes, the pedicels, and sometimes of the leafstalks also, usually close-lying. Calyx lobes reflexed in fruit. Rocky woods.

VIII. WALDSTEINIA Willd.

Stemless perennial herbs. Leaves 3–5-lobed or -divided. Flowers several, rather small, yellow, on a bracted scape. Calyx tube top-shaped; the limb spreading, with sometimes little bracts alternating with the lobes. Petals 5. Stamens many. Style 2–6. Akenes few, on a dry receptacle.

1. W. fragarioides Tratt. Barren Strawberry. A low herb with much the appearance of a strawberry plant. Leaflets 3, broadly wedge-shaped, crenate-dentate. Scapes many-flowered; the flowers rather pretty. Wooded hillsides.

IX. POTENTILLA L.

Perennial herbs, rarely shrubs. Leaves compound; stipules united to the petiole. Flowers white or yellow, rarely red; solitary or in cymes. Calyx hypogynous, 5-cleft, with 5 little bracts alternating with its lobes. Petals 5. Stamens many. Carpels usually many, on a dry convex or concave receptacle; styles falling off from the akenes as they mature.

B. Fl. species 5 (*Argentina*).

1. P. arguta Pursh. Upright Cinquefoil. An erect, stout, hairy plant, 1–4 ft. high. Basal leaves long-petioled, pinnate. Stem leaves few, each of 3–7 leaflets, the latter broadly ovate and cut-toothed or serrate, downy underneath. Flowers large, in dense terminal clusters; the petals whitish or cream color. Rocky hills.

2. P. monspeliensis L. Rough Cinquefoil. Annual or biennial. Stem rough-hairy, erect and stout, 6–30 in. high. Leaves of 3 leaflets, the lower petioled, the upper stem leaves sessile or nearly so,

leaflets cut-serrate. Flowers small, in a close, leafy cyme. Styles glandular-thickened at the base. In dry soil.

3. P. rivalis Nutt., var. **millegrana**. DIFFUSE CINQUEFOIL. Annual. Stems decumbent or ascending, commonly diffusely branched, 1¼–3 ft. high, clothed with long, soft hairs or nearly smooth. Leaves all but the uppermost of 3 leaflets and petioled; leaflets oblong, wedge-shaped, thin, deeply serrate. Flowers yellow, in loose, leafy cymes. Style somewhat thickened below. In damp soil W.

4. P. argentea L. SILVERY CINQUEFOIL. Stems prostrate or ascending and branching, woolly. Leaflets oblong, wedge-shaped, those of the upper leaves very narrow, with a few large, deeply cut teeth, smooth and green above, silvery beneath, with a dense coat of white wool. Flowers small and somewhat clustered, yellow. Dry fields and roadsides.

5. P. Anserina L. SILVERWEED. Stems spreading by slender runners, with many joints, silky-hairy. Leaves all basal, pinnate; leaflets 7–21, serrate, oblanceolate or obovate, nearly smooth above, white and silky-downy beneath. Flowers yellow, ½–1 in. in diameter. Style thread-like. River banks, brackish marshes, and borders of lakes.

6. P. canadensis L. COMMON CINQUEFOIL. Stems slender, procumbent, silky-hairy, sending out long runners. Leaflets obovate, wedge-shaped, appearing like 5 from the divisions of the 2 lateral ones. Peduncles 1-flowered in the axils of the leaves. Flowers yellow. Common in dry pastures and a troublesome weed.

X. FILIPENDULA Hill. (ULMARIA).

Tall perennial herbs. Leaves pinnately divided, with stipules. Flowers small, bisexual, in panicled cymes. Calyx 5-lobed. Petals 5, with claws. Stamens many, hypogynous, borne on a flat or slightly hollowed receptacle. Pistils 5–15, distinct. Carpels when ripe 1–2-seeded, looking like follicles but not splitting open.

1. F. rubra Hill. QUEEN OF THE PRAIRIE. Smooth, branching, 2–8 ft. high. Leaves very large, of 3–7 pinnately arranged leaflets, often with smaller ones between, the lobes cut or toothed; terminal leaflet much larger, 7–9-parted. Flowers showy, pink, fragrant, about ⅓ in. in diameter. Meadows and prairies, especially in moist soil, sometimes cultivated.

2. F. Ulmaria Maxim. MEADOWSWEET. Stem 1–3 ft. high. Leaves lyrate, interruptedly pinnate, white-downy beneath. Flowers yellowish-white, small, fragrant, in a dense compound cyme. Pods spirally twisted. Cultivated from Europe and sometimes escaping.

XI. GEUM L.

Erect perennial herbs. Basal leaves crowded, pinnate, with a very large terminal leaflet. Flowers and fruit much as in *Potentilla*, but the akenes tailed with the remains of the styles. B. Fl. species 5 (*Sieversia*).

1. **G. canadense** Jacq. White Avens. Stem erect, branching above, smooth or finely downy, 18–24 in. high. Basal leaves pinnate, or the earliest simple and rounded, long-petioled, serrate or dentate; terminal lobe larger than the lateral lobes; stem leaves short-petioled, 2–5-lobed or -parted. Flowers on slender peduncles. Petals white, not longer than the sepals. Styles jointed near the middle, the lower portion persistent and hooked. Ovaries and receptacle hairy; head of fruit globose. Rich woods.*

2. **G. virginianum** L. Stem 2–3 ft. high, stout and bristly-hairy. Lower leaves and basal leaves pinnate, varying greatly; upper leaves mostly of 3 leaflets or 3-parted. Petals white or pale yellow, small, shorter than the calyx lobes. Heads of fruit large, on stout, hairy peduncles; the receptacle nearly or quite smooth. Borders of woods and damp thickets.

3. **G. macrophyllum** Willd. Large-leaved Avens. Stem stout, erect, bristly-hairy, 1–3 ft. high. Basal leaves lyrate-pinnate, the terminal portion much the largest, kidney-shaped or heart-shaped; lateral leaflets 3–6, with smaller ones between. Flowers terminal, yellow. Style $\frac{1}{4}$–$\frac{1}{3}$ in. long, downy below. In low grounds.

4. **G. rivale** L. Water Avens, Purple Avens, Chocolate Root. Stem $1\frac{1}{2}$–2 ft. high, somewhat downy or hairy, simple or nearly so. Basal leaves lyrate and somewhat pinnate, with the divisions irregular; stem leaves few, of 3 leaflets or 3-lobed. Flowers rather large. Petals purplish-yellow, as long as the brownish-purple calyx lobes. Styles long, purplish; stigmas thread-like, feathered with soft hairs, especially in fruit. Wet meadows.

5. **G. triflorum** Pursh. Long-plumed Purple Avens. Softly downy, scapes 6–18 in. high. Basal leaves petioled, tufted, pinnate; the larger leaflets obovate or oval, cut-toothed, with many smaller ones between. Flowers 3–8, light purple. Styles $1\frac{1}{2}$–2 in. long. In dry or rocky soil.

XII. RUBUS L.

Mostly prickly shrubs, producing runners. Leaves alternate, simple or compound; stipules united to the petiole. Flowers in terminal and axillary clusters, rarely solitary, white (in one American species (No. 3) purple rose color). Calyx hypogynous,

with a broad tube; its lobes 5, persistent. Petals 5. Stamens many. Carpels many, distinct, on a convex receptacle. Fruit a cluster of little 1-seeded drupes on a dry or somewhat juicy receptacle.

A. Raspberries

Grains of the fruit, when ripe, usually falling off from the receptacle and leaving the latter with the calyx.

1. **R. idæus** L., var. **aculeatissimus.** Red Raspberry. Stems widely branching, biennial, not rooting at the tips, armed with weak bristles and with a few hooked prickles. Leaves petioled, of 3–5 ovate leaflets which are sharply serrate and sometimes lobed, downy beneath. Flowers in terminal and axillary racemes and panicles, pedicels drooping. Fruit hemispherical or conical, red, separating easily from the receptacle. Common on mountains and burned clearings, Iowa and N., and widely cultivated.*

2. **R. occidentalis** L. Black Raspberry. Stems long and slender, often recurved and rooting at the tips, armed with weak, hooked prickles. Leaves petioled, 3–5 ovate leaflets, coarsely serrate, white-downy below. Flowers white, in compact terminal corymbs. Pedicels erect or ascending. Fruit black, hemispherical, separating easily from the receptacle. Common on borders of woods, Missouri and N., widely cultivated.*

3. **R. odoratus** L. Flowering Raspberry (often wrongly called Mulberry). Stems shrubby, rather stout, 3–5 ft. high, not prickly; the young shoots, peduncles, and calyx covered with sticky glandular hairs. Leaves large, simple, 3–5-lobed. Flowers showy, rose-purple, 1–2 in. in diameter, on many-flowered peduncles. Fruit red, flattish, eatable. Rather common E. and N., and often cultivated.

4. **R. triflorus** Richards. Dwarf Raspberry (also wrongly known as Mulberry). A slender, trailing plant, almost entirely herbaceous, not prickly but sometimes bristly. Leaves compound, usually of 3 but sometimes of 5 thin, ovate-lanceolate, frequently unsymmetrical leaflets, which are coarsely doubly serrate and often cleft or lobed, with a shining upper surface. Flowers small, on 1–3-flowered peduncles. Fruit usually few-grained, rather dark red, eatable, the grains adhering somewhat to the receptacle. Common, especially N., in hilly woods, often forming a dense carpet in the partial shade of pines.

B. Blackberries

Grains of the ripe fruit falling from the calyx along with the soft, eatable receptacle.

5. **R. allegheniensis** Porter. High Blackberry. Stem shrubby, erect or bending, 3–7 ft. high, glandular-downy above and with stout,

straightish prickles below. Leaves petioled, of 3–7 ovate leaflets which are acute, irregularly serrate, soft-hairy beneath. Flowers racemed, the lower ones leafy-bracted. Petals white, obovate, much longer than the taper-pointed sepals. Fruit long, of small drupelets. Common in thickets.*

6. R. cuneifolius Pursh. SAND BLACKBERRY. Stem shrubby, erect or diffuse, 2–3 ft. high; prickles straight or recurved. Leaves petioled, 3–5-foliate; leaflets obovate, serrate towards the apex, wedge-shaped towards the base, rough above, white downy-woolly beneath. Racemes mainly terminal, few-flowered. Petals white, longer than the sepals. Fruit ovoid, black, smaller than the preceding. Common in old fields.*

7. R. hispidus L. RUNNING SWAMP BLACKBERRY. Stem trailing or prostrate, often several feet in length, armed with recurved prickles. Leaves petioled, mostly of 3 leaflets; leaflets obovate, obtuse, thick, dark green and shining above. Flowering branches commonly erect, few-flowered, flowers white. Fruit small, reddish, turning nearly black. In swamps and low ground.

8. R. villosus Ait. LOW BLACKBERRY, DEWBERRY. Stems shrubby, trailing widely, 3–10 ft. long, somewhat prickly. Leaflets usually 3, but sometimes 5 or 7, ovate, acute, sharply (and doubly) cut-serrate, thin. Racemes upright on the short branches, 1–3-flowered. Fruit roundish, of fewer and larger grains than No. 5, very sweet when fully ripe. Common N., in stony or gravelly fields.

XIII. ROSA L.

Erect running or climbing prickly shrubs. Leaves pinnate, leaflets serrate, stipules united to the petiole. Calyx tube urn-shaped, with a rather narrow mouth. Petals (in single roses) 5. Stamens many, inserted around the inside of the mouth of the calyx tube. Ovaries many, hairy, ripening into bony akenes, inclosed in the rather fleshy and sometimes eatable calyx tube.

1. R. pratincola Greene. Stems densely prickly, 1–2 ft. high. Stipules narrow, usually with glandular teeth or a fringe of glandular hairs toward the tip; leaflets 7–11, varying from elliptical to nearly obovate, obtuse at the tip, narrowed at the base, simply toothed or serrate, rather firm and distinctly veined. Flowers usually in corymbs; sepals lanceolate, taper-pointed. Fruit globose, smooth. Prairies, especially W.

2. R. blanda Ait. EARLY WILD ROSE. Stems 1–3 ft. high, usually without prickles; stipules broad. Flowers generally large, corymbed or solitary; sepals after flowering closing over the mouth of the calyx tube and persistent. Rocks and rocky shores.

3. R. Woodsii Lindl. Stems 3–36 in. high, with slender spines which are often wanting above. Stipules rather broad, entire; leaflets usually 5–7, varying from obovate to lanceolate, rather obtuse at the apex, narrowed at the base, somewhat serrate. Flowers corymbed or solitary. Sepals erect on the globose or somewhat ovoid fruit. Prairies W.

4. R. rubiginosa L. SWEETBRIER. Stem erect or curving, armed with stout recurved prickles. Leaves with 5–7 leaflets, the latter broadly oval, coarsely serrate, glandular-bristly beneath, aromatic. Flowers white or pink. Sepals widely spreading, deciduous. Fruit obovate, slightly bristly. Common in cultivation and sometimes wild.*

5. R. carolina L. SWAMP ROSE. Stems 4–8 ft. high, with stout and generally recurved prickles. Stipules long and narrow; leaflets commonly downy beneath, finely serrate. Flowers several in a corymb, bright rose color. Sepals spreading and falling off after flowering. Damp woods and borders of swamps.

6. R. virginiana Mill. DWARF WILD ROSE. Stems varying in height from less than a foot to 6 ft., with stout, somewhat hooked prickles. Stipules rather broad; leaflets small, thickish and glossy above, coarsely toothed toward the tip. Flowers corymbed or solitary, pale rose color. Sepals spreading and falling off after flowering. Moist ground and swamps.

7. R. humilis Marsh. PASTURE ROSE. Stem erect, branched, usually armed with stout stipular prickles and with bristles, but sometimes nearly smooth, 1–3 ft. tall. Leaves mostly of 5 leaflets; stipules entire; leaflets oblong-lanceolate or oval, shining above, pale beneath, sharply serrate. Flowers solitary or 2–3 together, 2–3 in. broad, pink. Peduncles and calyx glandular-downy. Sepals leaf-like, spreading, finally deciduous. Styles distinct. Fruit globose, bristly-hairy. On dry soil; our most common wild rose. S.*

XIV. PRUNUS L.

Trees or shrubs. Leaves simple, with stipules, which are often small or fall off early. Calyx with a bell-shaped or urn-shaped tube and 5-lobed spreading limb, falling off after flowering. Petals 5; stamens 3–5 times as numerous, or indefinite, inserted on the throat of the calyx tube. Pistil 1, long-styled, with 2 ovules, ripening into a single drupe.

B. Fl. species 8 (*Amygdalus*).

A. *Stone more or less spherical; fruit smooth when ripe. Branches not spiny.* (*Cherries.*)

1. P. serotina Ehrh. WILD BLACK CHERRY. Often becoming a large tree; bark on old trees rough, nearly black. Leaves rather

thick, oval to lanceolate-ovate, acute or taper-pointed at the apex, finely serrate with calloused teeth, smooth above, downy on the veins beneath. Racemes terminal, long and spreading. Flowers white. Fruit globose, about $\frac{1}{4}$ in. in diameter, purplish-black. In rich woods. Wood much used in cabinet-making.*

2. P. virginiana L. CHOKECHERRY. A shrub or small tree, 5–20 ft. high. Leaves thin, oval or obovate, pale, pointed, sharply serrate. Flowers small, white, in short racemes. Fruit bright red, turning at length to dark crimson, very puckery until fully ripe. River banks and thickets.

3. P. pennsylvanica L. f. WILD RED CHERRY. A tree 20–30 ft. high, with light, reddish-brown bark. Leaves oval or oblong-lanceolate, pointed, finely serrate, with both sides green, smooth and shining. Flowers long-pediceled, many in a cluster, the clusters lateral, leafless. Fruit globose, very small, light red, with thin sour pulp and globular stone. In rocky woods.

4. P. Besseyi Bailey. WESTERN SAND CHERRY. A shrub 1–4 ft. high, often with spreading and prostrate branches. Leaves usually elliptic or oblong-elliptic, with appressed teeth. Flowers sessile in lateral umbels, $\frac{1}{3}$ in. to nearly $\frac{1}{2}$ in. in diameter, opening with the leaves. Fruit black, mottled, or yellowish, $\frac{1}{2}$–$\frac{2}{3}$ in. in diameter, bitter and astringent. Prairies W.

5. P. Cerasus L. CHERRY. Often becoming a large tree. Leaves oval or ovate, acute or taper-pointed at the apex, rounded at the base, irregularly serrate-dentate, smooth on both sides, resinous when young. Flowers in lateral umbels, white; pedicels long and slender. Fruit globose, red or black. Cultivated from Europe. This is the species from which most of our sour cultivated varieties have been developed.*

B. *Stone oval, compressed; fruit smooth when ripe. Branches often spiny. (Plums.)*

6. P. angustifolia Marsh. CHICKASAW PLUM. A small tree with spiny branches. Leaves lanceolate or oblong-lanceolate, acute at the apex, usually obtuse at the base, finely and sharply serrate, rather thin, smooth. Flowers in lateral, sessile umbels, pedicels short. Calyx smooth. Fruit yellowish-red, subglobose, skin thin, stone only slightly compressed. In old fields S.*

7. P. americana Marsh. WILD PLUM. A small tree, bark thick and rough, branches spiny. Leaves ovate or obovate, acuminate at the apex, rounded or cordate at the base, sharply serrate, rather thick, downy beneath; petioles glandular. Flowers in lateral, sessile umbels, appearing with or before the leaves; pedicels $\frac{1}{2}$–$\frac{3}{4}$ in. long, flowers $\frac{1}{2}$–$\frac{3}{4}$ in. in diameter. Calyx downy within. Fruit globose, red or yellow, $\frac{1}{2}$–1 in. in diameter. Common in woods.*

C. *Stone deeply furrowed and pitted; fruit downy when ripe. Branches not spiny. (Peaches and almonds.)*

8. P. persica Stokes. Peach. A tree with a rounded top; bark nearly smooth. Leaves lanceolate, taper-pointed, finely serrate, smooth on both sides; petioles usually bearing 2 or 4 crescent-shaped or cup-shaped glands. Flowers pink, scaly-bracted. Fruit ovoid, with a seam along one side. Often escaped from cultivation.*

47. LEGUMINOSÆ. Pulse Family

Herbs, shrubs, or trees. Leaves alternate, usually compound (either pinnately or palmately), with stipules, the leaflets mostly entire. Calyx of 5 sepals, which are more or less united, often somewhat zygomorphic. Corolla of 5 petals,

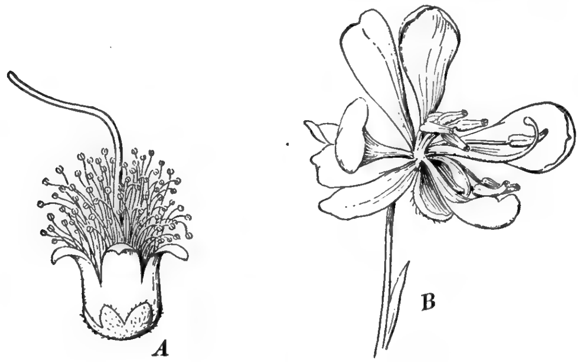


Fig. 20. Pulse Family

A, actinomorphic corolla (*Acacia cinerascens*); *B*, zygomorphic corolla (*Cassia marilandica*). (After Schnizlein)

often papilionaceous (Fig. 21) or somewhat actinomorphic, in No. XVI much reduced. Stamens diadelphous (Fig. 22), monadelphous, or distinct. Ovary simple, superior. Fruit usually a 1-celled pod (Fig. 22). Seeds one or several, without endosperm. A large and very important family, containing about 8000 species.

A

Flower actinomorphic, small. Stamens hypogynous. Leaves twice pinnate.

Petals not united to each other. Stamens 5 or 10. Pod smooth. Desmanthus, I

Corolla gamopetalous, 5-cleft. Stamens 8 or 10. Pod minutely prickly or rough. Schrankia, II

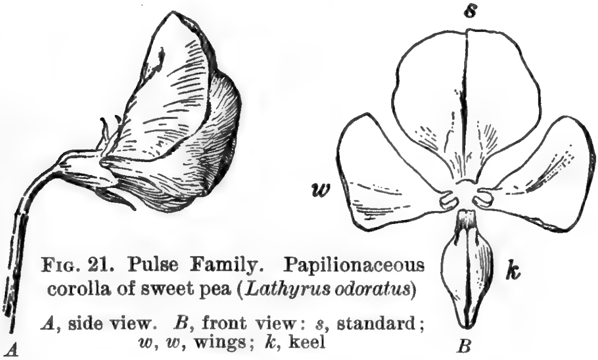


FIG. 21. Pulse Family. Papilionaceous corolla of sweet pea (*Lathyrus odoratus*)

A, side view. *B*, front view: *s*, standard; *w*, *w*, wings; *k*, keel

B

Trees. Flowers somewhat or not at all papilionaceous, sometimes almost actinomorphic. The upper petal inside the others in the bud. Stamens 10 or less, usually not united to each other, borne on the calyx.

Flowers imperfectly papilionaceous. Leaves simple. Cercis, V
Flowers not papilionaceous. Thornless. Gymnocladus, III
Flowers not papilionaceous. Thorny. Gleditsia, IV

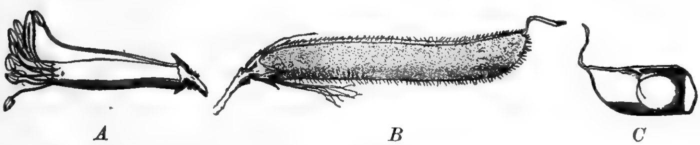


FIG. 22

A, stamens and pistil of sweet pea (magnified); *B*, fruit; *C*, part of fruit, showing one seed

C

Herbs or trees. Flowers decidedly papilionaceous. The upper petal external in bud and inclosing the others. Stamens 10, not united to each other.

Trees.	Cladrastis, VII
Herbs. Pod inflated.	Baptisia, VI
Herbs. Pod elongated, necklace-shaped.	Sophora, VIII

D

Shrubs with a corolla of one petal only. Amorpha, XVI

E

Herbs, shrubs, or trees. Flowers decidedly papilionaceous. Stamens monadelphous or diadelphous (in the latter case usually 9 and 1).

1. Stamens with anthers of two forms.
   - (*a*) Herbs. Leaves usually with many leaflets. Lupinus, IX
   - (*b*) Herbs. Leaves with 3 entire leaflets. Psoralea, XV
   - (*c*) Trees. Laburnum, X
   - (*d*) Low shrubs. Cytisus, XI
2. Anthers all alike. Leaves usually with 3 leaflets.
   - (*a*) Pod coiled. Medicago, XIV
   - (*b*) Pod small, not coiled. Flowers in racemes. Melilotus, XIII
   - (*c*) Pod small, not coiled. Flowers in heads. Trifolium, XII
   - (*d*) Pod large, flattened, bur-like. Desmodium, XX
   - (*e*) Pod large, not much flattened. Phaseolus, XXIV
3. Anthers all alike. Leaves odd-pinnate, with more than 3 leaflets.
   - (*a*) Low, woody shrubs. Amorpha, XVI
   - (*b*) Tall, twining shrubs. Wisteria, XVIII
   - (*c*) Trees. Robinia, XVII
   - (*d*) Herbs. Astragalus, XIX
4. Anthers all alike. Leaves pinnate, the midrib prolonged into a tendril.

(*a*) Leaflets usually many pairs. Style slender, bearded only at the tip or all round the upper portion. Pod 2–several-seeded. Vicia, XXI

(*b*) Leaflets few or several pairs. Style bearded along one face only. Pod several-seeded. Lathyrus, XXII

(*c*) Leaflets 1–3 pairs. Style enlarged above, grooved on the back. Pod several-seeded; seeds large, globular or nearly so. Pisum, XXIII

I. DESMANTHUS Willd. (ACUAN)

Shrubs or perennial herbs. Stems erect or diffuse, smooth. Leaves abruptly twice-pinnate; stipules small. Flowers in heads or spikes, on axillary peduncles, the upper bisexual, the lower often staminate or neutral. Calyx 5-toothed. Corolla of 5 distinct petals or 5-cleft. Stamens 5–10, distinct. Ovary nearly sessile, flat, several-seeded.*

1. **D. illinoensis** Mac M. DESMANTHUS. Stem erect or ascending, smooth, 1–4 ft. high. Pinnæ 6–14 pairs, each with a minute gland at the base; leaflets 20–30 pairs, small, linear. Heads globose. Stamens 5. Pods several, on a peduncle 2–3 in. long, curved, flat, 2-valved, 3–6-seeded. Open, sandy fields.*

II. SCHRANKIA Willd. (MORONGIA)

Perennial herbs. Stems reclining or prostrate, prickly, 2–5 ft. long. Leaves twice-pinnate; stipules bristly. Flowers bisexual or somewhat monœcious, in axillary peduncled heads. Calyx minute. Corolla tubular, 5-cleft. Stamens 8–10, distinct. Pod long, prickly, 1-celled.*

1. **S. uncinata** Willd. SENSITIVE BRIER, SENSITIVE ROSE, SHAME VINE. Plant covered with hooked prickles. Leaflets elliptical, with a conspicuous network of veins beneath; leaves closing gradually after being touched. Flowers rose-colored. Pods nearly cylindrical, 2 in. long. Dry, sandy soil and rolling prairies, especially S. and W.

III. GYMNOCLADUS Lam.

A large, thornless tree, its twigs few and stout. Leaves very large, twice pinnately compound, without stipules. Flowers actinomorphic, whitish, diœcious or somewhat monœcious, in

racemes at the ends of the branches. Calyx tube rather long, its 5 lobes spreading. Petals oblong, all alike, inserted with the stamens on the throat of the calyx. Stamens of the fertile flowers usually not pollen-bearing. Pod hard, flat, partly filled with a sweet substance, slow in opening. Seeds several, flattish, over ½ in. in diameter, very hard and shining.

1. **G. dioica** Koch. KENTUCKY COFFEE TREE. Tree 50 ft. or more in height, with rough gray bark. Leaves 2–3 ft. long, the leaflets vertical. Pods sometimes nearly 1 ft. long. Rich soil and river bottoms, especially S. and W.

IV. GLEDITSIA L.

Large trees; bark dark-colored, nearly smooth. Leaves usually pinnately twice compound; leaflets serrate. Flowers somewhat monœcious, in small spike-like racemes. Calyx spreading, 3–5-cleft. Petals as many as the sepals and inserted at the summit of the tube. Stamens 5–10, distinct, inserted with the petals. Ovary nearly sessile, ovoid or elongated. Fruit a 1-or many-seeded, leathery pod.*

1. **G. triacanthos** L. HONEY LOCUST. A large tree, usually armed with stout, branched thorns, which are sometimes a foot or more in length. Leaves petioled; leaflets short-stalked, lanceolate-oblong, base inequilateral, smooth above, often downy below. Racemes solitary or in small clusters, drooping. Flowers inconspicuous, greenish. Pod linear-oblong, often 12–15 in. long by 1 in. wide, twisted, many-seeded, smooth and shiny, pulpy within. In rich woods.

V. CERCIS L.

Trees. Leaves simple, with stipules. Flowers in axillary clusters, somewhat papilionaceous. Calyx bell-shaped, 5-toothed. Stamens 10, distinct. Ovary short-stalked; ovules several. Fruit a flattened pod.

1. **C. canadensis** L. REDBUD. A small tree, 10–20 ft. high; wood hard but weak; bark smooth, dark-colored. Leaves broadly cordate, abruptly acute, rather thick, very smooth above, often slightly downy below. Flowers several in a cluster, appearing before the leaves, pinkish-purple. Pod oblong, compressed, many-seeded. Common on rich soil, especially S.*

VI. BAPTISIA Vent.

Perennial herbs; stems erect, widely branched. Leaves simple or palmate, of 3 leaflets. Flowers in racemes. Calyx 4–5-lobed, persistent, the upper lobe usually longer and notched; standard rounded, its sides reflexed, wings about as long as the keel. Stamens 10, distinct. Pod stalked, long-pointed by the remains of the style. Plants usually becoming black in drying.*

1. B. tinctoria R. Br. Wild Indigo. Stem smooth, slender, 2–4 ft. high; branches slender. Leaves of 3 leaflets, on short petioles, the upper nearly sessile; stipules minute, quickly deciduous. Leaflets obovate to oblanceolate, obtuse at the apex, wedge-shaped at the base, entire. Racemes numerous, terminal. Flowers yellow, ½ in. long. Pod globose, ovoid, on a stalk about the length of the calyx, point long and slender. Plant blackening in drying. Common on dry, sandy soil.*

2. B. bracteata Muhl. Low, hairy, and branching. Leaves nearly sessile; leaflets oblanceolate or obovate-spatulate; stipules triangular-ovate, large, persistent; bracts large and leaf-like. Racemes long. Flowers large, yellowish-white. Pod ovoid, swollen. Prairies and open woods W. and S.

3. B. leucantha T. & G. Stout, smooth, and covered with a bloom, 3 ft. or more high, with spreading branches. Petioles short; lanceolate stipules and bracts falling off early. Racemes erect. Flowers large, white. Pods ellipsoidal, 2 in. long, borne on a stalk twice as long as the calyx. Rich river bottoms and prairies.

4. B. alba R. Br. White Wild Indigo. Stem smooth and with a bloom, often purple, 2–3 ft. high; branches slender, spreading. Leaves petioled, with 3 leaflets; stipules minute, soon deciduous. Flowers white, mostly in a single raceme which is 1–3 ft. long, with occasionally lateral, few-flowered racemes. Pod linear-oblong, the point very slender and soon deciduous. Plant unchanged in drying. In damp soil.*

5. B. australis R. Br. Blue False Indigo. Stem smooth, stout, 2–4 ft. high. Leaves of 3 leaflets, short-petioled; stipules lanceolate, persistent, longer than the petioles; leaflets oblong, wedge-shaped or narrowly obovate, entire. Flowers bright blue, 1 in. long, in terminal, erect, loosely flowered racemes; stalk about the length of the calyx. Pod oblong, with a slender, persistent point. Banks of rivers; often cultivated for ornament.*

VII. CLADRASTIS Raf.

A moderate-sized tree, with smooth dark gray bark and yellow wood. Leaves of 7–11 smooth oval or ovate leaflets.

Flowers creamy-white, in long, drooping panicles. Calyx 5-toothed. Standard large, nearly round, reflexed; petals of the keel and wings separate and straight. Stamens 10, unconnected with each other. Pod borne on a short stalk above the calyx. Seeds 4–6.

1. **C. lutea** Koch. YELLOW WOOD. Tree 50 ft. or less in height, much branched, with a round, spreading top. Hillsides, in fertile soil, south central states. Also considerably planted as a shade tree.

VIII. SOPHORA L.

Shrubby or herbaceous perennials. Leaves odd-pinnate, with many leaflets. Calyx bell-shaped, with 5 short teeth. Standard roundish; keel nearly straight. Stamens almost or quite distinct; anthers versatile. Pod stalked, leathery or fleshy, nearly cylindrical but more or less contracted between the seeds, not splitting open.

1. **S. sericea** Nutt. Herbaceous with a woody base, erect, 6–12 in. high, covered with silky silvery down. Leaflets 7–25, obovate or nearly so, obtuse, narrowed at the base, $\frac{1}{4}$–$\frac{1}{2}$ in. long. Flowers white. Pod slender, dry, few-seeded. Prairies W. and S.W.

IX. LUPINUS L.

Biennial or perennial herbs. Leaves simple or palmately compound. Flowers showy, in terminal racemes. Calyx 2-lipped, 5-toothed. Standard round, with the sides reflexed; keel scythe-shaped. Stamens monadelphous; anthers alternately oblong and roundish. Ovary sessile; matured pod oblong, several-seeded, often compressed between the seeds.*

1. **L. perennis** L. Perennial. Stem erect, downy, 12–18 in. high. Leaves palmately 7–9-foliate; leaflets obovate or oblanceolate, obtuse and mucronate at the apex, slightly downy; petiole slender; stipules small. Racemes terminal, slender, loosely many-flowered. Flowers purple, blue, pink, or white. Pod oblong, densely downy, few-seeded. Dry, sandy soil.*

X. LABURNUM Medic.

Trees or shrubs. Leaves of 3 leaflets, with very small stipules or none. Flowers golden-yellow, in slender, drooping racemes. Calyx 2-lipped, the upper lip 2-toothed, the lower 3-toothed. Standard ovate, upright, of the same length as the

straight wings. Stamens diadelphous (9 and 1). Ovary and pod somewhat stalked above the calyx, several-seeded.

1. **L. vulgare** Griseb. LABURNUM, GOLDEN CHAIN. A small tree, with smooth, greenish bark. Leaves with slender petioles; leaflets oblong-ovate, acute at the base, taper-pointed, downy beneath. Flowers showy, in graceful racemes. Cultivated from Europe.

XI. CYTISUS L.

Shrubs, rarely spiny. Leaves of 1–3 leaflets or none; stipules very small. Calyx 2-lipped, the upper lip slightly 2-toothed, the lower 3-toothed. Keel straight or a little curved, blunt, turned down after flowering. Stamens with their filaments all united; anthers every other one short and attached by its center, the alternate ones long and fastened by their bases. Style curved in, or, after the flower opens, coiled up. Pod flat, long, many-seeded.

1. **C. canariensis** Dumont. A shrub with many rather stiff, erect, slender branches. Leaves abundant, very small, covered with soft gray hairs; leaflets 3, obovate. Flowers rather small, yellow, in somewhat erect racemes. Cultivated in greenhouses. From the Canary Islands.

XII. TRIFOLIUM L.

Annual, biennial, or perennial herbs. Stems more or less spreading. Leaves petioled, of 3 toothed or serrate leaflets; stipules united to the petioles. Flowers white, yellow, or red, in heads. Calyx 5-cleft, the teeth nearly equal, awl-shaped. Petals withering-persistent; keel shorter than the wings. Stamens diadelphous. Pod smooth, 1–6-seeded, scarcely opening.*

1. **T. arvense** L. RABBIT FOOT CLOVER, STONE CLOVER. Annual, silky-downy, erect, branching, 5–10 in. high. Leaflets oblanceolate or linear, minutely toothed above. Heads terminal, peduncled. Calyx teeth very silky-hairy, longer than the whitish corolla. Old fields, railroad embankments, and waste ground. Naturalized from Europe.

2. **T. incarnatum** L. CRIMSON CLOVER. Annual. Stem erect, somewhat branched, downy, 1–2 ft. high. Lower leaves long-petioled, the upper short-petioled; leaflets obovate or wedge-shaped, toothed at the apex. Flowers bright crimson, sessile, in terminal heads which finally become much elongated. Calyx silky, its lobes long and plumose. Introduced from Europe and cultivated for fodder.

3. **T. pratense** L. RED CLOVER. Biennial or short-lived perennial. Stems spreading, branching, downy, 1–3 ft. long. Leaves long-petioled; stipules large; leaflets oval to obovate, finely toothed, often with a dark triangular spot near the center. Flowers red or purple, in globose heads, erect in fruit. Calyx teeth bristle-shaped, hairy. Pod 1–3-seeded. Introduced from Europe and widely cultivated.*

4. **T. repens** L. WHITE CLOVER. Perennial. Stems widely branching at the base, prostrate and creeping, nearly smooth, 6–12 in. long. Leaves long-petioled; leaflets oval, obovate, or obcordate, minutely toothed. Heads globose, long-peduncled. Flowers white, reflexed in fruit. Pod 3–4-seeded. Common about houses and in pastures.*

5. **T. hybridum** L. ALSIKE CLOVER. Perennial, considerably resembling No. 4, but the stems more upright and stouter. Leaflets varying from broadly ovate to ovate-lanceolate, mucronate or slightly notched, the margins fringed with hairs; stipules prolonged into bristle-like points. Flowers rose color and white, very fragrant. In fields and along roadsides. Introduced from Europe.

6. **T. carolinianum** Michx. CAROLINA CLOVER. Perennial. Stems spreading or ascending, much-branched, downy, 6–10 in. long. Leaves short-petioled; leaflets small, obovate or obcordate, slightly toothed. Heads small, globose, on long peduncles. Flowers white, tinged with purple, reflexed in fruit. Pod 4-seeded. Common in waste places S.*

7. **T. procumbens** L. LOW HOP CLOVER. Annual. Stem slender, erect or spreading, downy, 6–10 in. long. Leaves short-petioled; leaflets obovate or obcordate, finely dentate, the middle one distinctly stalked; stipules lance-ovate. Flowers yellow, reflexed in fruit. Pod 1-seeded. Common on clay soil, in waste places. Naturalized from Europe.*

XIII. MELILOTUS Hill.

Annual or biennial herbs. Leaves petioled, of 3 leaflets. Flowers small, white or yellow, in dense axillary and terminal racemes. Calyx 5-toothed, the teeth nearly equal. Standard erect, wings and keel cohering. Stamens 10, diadelphous. Pod longer than the calyx, 1–4-seeded.*

1. **M. alba** Lam. MELILOTUS. Biennial. Stem erect, branching, smooth or the young branches slightly downy. Leaflets oblong or oblanceolate, rounded or truncate at the apex, serrate; stipules small. Racemes long, slender, erect. Flowers white. Standard longer than the wings and keel. Pod ovoid, wrinkled, drooping, mostly 1-seeded, scarcely opening. Common as a weed and widely cultivated.*

2. M. officinalis Willd. YELLOW SWEET CLOVER. A stout, upright, branching herb, 2–4 ft. high, looking much like the preceding species, but coarser. Flowers yellow. Waste ground and roadsides. Naturalized from Europe.

XIV. MEDICAGO L.

Annual or perennial herbs. Leaves petioled, of 3 toothed leaflets. Flowers in terminal and axillary spikes or racemes. Calyx 5-toothed, the teeth short and slender. Standard oblong, much longer than the wings or keel. Stamens 10, diadelphous. Ovary sessile. Pod 1–several-seeded, coiled, not splitting open, often spiny.*

1. M. sativa L. ALFALFA. Perennial. Stems erect, branching, downy when young, becoming smooth with age, 2–3 ft. high. Leaves short-petioled; leaflets obovate, sharply dentate towards the apex, obtuse or sometimes notched or mucronate; stipules lanceolate, entire. Flowers blue, small, in rather close spikes. Pods downy, coiled, few-seeded. Introduced from Europe, and cultivated for hay and pasture.*

2. M. lupulina L. BLACK MEDICK, NONESUCH. An annual or biennial, much-branched, reclining herb, with stems 6–20 in. long. Leaves very short-petioled; leaflets obovate, acute, $\frac{1}{4}$–$\frac{2}{3}$ in. long, toothed near the tip. Flowers small, yellow, in short spikes. Pods very small, 1-seeded, kidney-shaped, black. Roadsides and waste ground, adventive from Europe.

XV. PSORALEA L.

Perennial herbs; whole plant glandular-dotted. Leaves of 3–5 leaflets; stipules united with the petioles. Flowers in axillary or terminal spikes or racemes. Calyx 5-cleft, the lobes nearly equal. Standard ovate or orbicular; keel incurved, obtuse. Stamens monadelphous or diadelphous, 5 of the anthers often undeveloped. Ovary nearly sessile. Pod included in the calyx, often wrinkled, remaining closed, 1-seeded.*

1. P. pedunculata Vail. SAMSON'S SNAKEROOT. Stem erect, slender, branching above, downy, 1–2 ft. high. Leaves of 3 leaflets; petioles shorter than the leaflets; stipules awl-shaped; leaflets elliptical or oblong-lanceolate, sparingly glandular-dotted, the terminal one stalked. Loosely flowered spikes axillary and terminal, on peduncles much longer than the leaves. Flowers blue or purple, about $\frac{1}{3}$ in. long. Pod compressed-globose, wrinkled transversely. Dry soil.*

2. P. tenuiflora Pursh. Upright, slender, bushy and branching, 2–4 ft. high, covered when young with a fine grayish down. Leaves

palmately compound, with 3–5 linear to obovate-oblong leaflets, covered with glandular dots. Flowers $\frac{1}{6}$–$\frac{1}{4}$ in. long, loosely racemed. Pod rough with glands. Prairies W.

3. P. argophylla Pursh. SILVER-LEAVED PSORALEA. Densely silvery downy, with white, close-lying hairs. Stem often zigzag, 1–3 ft. high. Leaves palmate; leaflets 3–5, elliptical-lanceolate, oval or obovate. Spikes interrupted, the peduncles longer than the leaves. Flowers blue or purplish, $\frac{1}{3}$ in. or more long. Pod ovate, beak straight. Prairies, especially N.W.

4. P. esculenta Pursh. POMME BLANCHE, TIPSIN, DAKOTA TURNIP. Clothed with roughish hairs. Stem 5–15 in. high, erect and stout. Root turnip-shaped, starchy, eatable. Leaves palmately compound, with 5 lance-oblong leaflets. Flowers $\frac{1}{2}$ in. long, in a dense ellipsoidal spike. Pod hairy, with a pointed tip. High prairies or plains, especially N.W.

XVI. AMORPHA L.

Small shrubs, glandular-dotted. Leaves odd-pinnate. Flowers purple, blue, or white, in slender spikes or racemes. Calyx 5-toothed, persistent. Standard obovate, concave; wings and keel none. Stamens monadelphous, projecting much. Ovary sessile. Pod curved, glandular-roughened, 1–2-seeded, never opening.*

1. A. canescens Pursh. LEAD PLANT, SHOE STRINGS. A bushy, white, silky-downy shrub, 1–3 ft. high. Leaflets small and crowded, 21–49, oval or oblong-elliptical. Spikes mostly clustered at the summit, rather showy. Standard bright blue, roundish. Pod 1-seeded, slightly longer than the calyx. Prairies. Roots very long and tough, hence one common name.

2. A. microphylla Pursh. A bushy shrub about 1 ft. high. Leaves many, short-petioled; leaflets 13–19, rigid, oval or oblong. Racemes mostly solitary. Flowers fragrant; standard purplish. Prairies, especially N.W.

3. A. fruticosa L. FALSE INDIGO. A shrub, 6–15 ft. high, with smooth, dark-brown bark. Leaves petioled; leaflets 15–21, short-stalked, oblong, obtuse or notched, sparingly punctate with clear dots. Slender flowering spikes, panicled or solitary, 4–6 in. long. Flowers blue or purple. Calyx teeth short, nearly equal, downy. Pod glandular. River banks.*

XVII. ROBINIA L.

Trees or shrubs. Leaves odd-pinnate; stipules often spiny. Flowers showy, in axillary racemes. Calyx short, 5-toothed,

the two upper teeth shorter and partially united. Standard large, orbicular, reflexed, keel obtuse. Stamens diadelphous. Style bearded on one side. Pod compressed, several-seeded.*

1. **R. Pseudo-Acacia** L. BLACK LOCUST. A tree of medium size; bark rough and nearly black; twigs and leaves smooth. Leaflets 9–15, ovate or oblong, obtuse and slightly mucronate at the apex; stipules forming persistent spines. Racemes loose, pendulous, 3–5 in. long. Flowers white, fragrant. Pod smooth, 4–8-seeded. Introduced, and quite common; wood very durable when exposed to the weather, and extensively used for posts.*

XVIII. WISTERIA Nutt. (BRADLEYA)

Tall, twining shrubs. Leaves odd-pinnate. Racemes terminal. Flowers large and showy. Calyx 2-lipped, the upper lip 2-cleft, short, the lower longer and 3-cleft. Standard large, round, with 2 calloused ridges at the base; wings eared at the base; keel scythe-shaped. Pod long, stalked, leathery, 2-valved, several-seeded.*

1 **W. frutescens** Poir. WISTERIA. Stem climbing 30–40 ft., often 2–3 in. in diameter at the base; branches and leaves downy when young, becoming smoother with age. Leaves short-petioled; stipules minute; leaflets 9–17, ovate-lanceolate, acute at the apex, rounded at the base. Racemes large, densely flowered. Calyx downy. Corolla lilac-purple, wings with a short and a long appendage at the base. Pod 2–3 in. long, 2–4-seeded. River banks S. Often cultivated for ornament.*

2. **W. chinensis** DC. CHINESE WISTERIA. Larger and faster growing than No. 1. Racemes longer and more slender. Wing appendage at one side only of base. Seldom fruiting in this region. Cultivated from China or Japan.

XIX. ASTRAGALUS L.

Mostly perennial herbs. Leaves odd-pinnate. Flowers in spikes or racemes. Calyx 5-toothed. Petals long, erect, with claws. Standard narrow. Stamens diadelphous (9 and 1). Pod usually swollen, sometimes fleshy and eatable, several–many-seeded. [A large and very difficult genus; **mostly of far western species.**]

1. A. caryocarpus Ker. GROUND PLUM, BUFFALO APPLE. Covered with pale, close-lying down. Leaflets narrow, oblong. Flowers violet-purple, in a short, narrow raceme. Fruit looking like a small, green, pointed plum, about $\frac{2}{3}$ in. in diameter, eatable. N.W., and S. to Texas.

2. A. mexicanus A. DC. PRAIRIE APPLE. Smooth or with some loose hairs. Corolla cream color, with the tip bluish. Fruit globular, not pointed, eatable. Prairies, Illinois and S.W.

3. A. canadensis L. Erect, often tall (1–4 ft. high), more or less downy. Leaflets oblong, 21–27. Flowers pale greenish, in long spikes. Pod dry, 2-celled, sessile. River bottoms, prairies, and woods.

4. A. parviflorus MacM. Erect and slender, finely downy, somewhat ash-color, 1–2 ft. high. Leaflets 11–21, linear, obtuse, distant. Flowers purple, $\frac{1}{4}$–$\frac{1}{3}$ in. long, in long, slender racemes. Pods sessile, $\frac{1}{4}$ in. or less in length, concave on the back, white-hairy, becoming smooth. Prairies, especially N.W.

XX. DESMODIUM Desv. (MEIBOMIA)

Perennial herbs. Leaves pinnate, with stipules, usually with 3 leaflets. Flowers in axillary or terminal racemes, or sometimes in panicles, usually purple, sometimes pink or whitish. Calyx usually somewhat 2-lipped. Standard ovate, obovate, or roundish; wings attached to the straight or nearly straight keel by a little appendage projecting from each side of the keel. Stamens monadelphous (9 and 1) or all united at their bases. Pod flat, its lower margin variously lobed, separating into flat segments which are usually furnished with short, strong, hooked hairs, making the fruit a troublesome bur. [A large and rather difficult genus. Most of the species can only be distinguished by the fruit, which matures in late summer or autumn.]

XXI. VICIA L.

Climbing or spreading herbs. Leaves odd-pinnate, usually ending in a tendril. Leaflets many, entire or toothed at the tip; stipules half arrow-shaped. Flowers blue, purple, or yellow, in axillary racemes. Calyx teeth nearly equal. Wings united to the keel. Stamens diadelphous (9 and 1); filaments thread-shaped; anthers all alike. Style bent, smooth or downy all round or bearded below the stigma; ovules usually many. Pod flattened, 2–several-seeded. Seeds globular.

1. **V. sativa** L. COMMON VETCH. Annual. Stem simple, smooth, reclining, 1–3 ft. long. Leaves short-petioled; leaflets 2–5 pairs, obovate-oblong to linear, obtuse, notched and mucronate at the apex. Flowers in pairs, nearly sessile in the axils, pale purple, $\frac{3}{4}$ in. or less in length. Pod linear, several-seeded. In gravelly soil. Introduced from Europe.

2. **V. caroliniana** Walt. Perennial. Smooth or nearly so, 4–6 ft. high. Leaflets 8–24, narrowly oblong, blunt. Peduncles loosely flowered. Flowers small, whitish or tipped with pale purple. River banks.

3. **V. americana** Muhl. WILD VETCH, BUFFALO PEA. Perennial. Smooth, 1–3 ft. high. Leaflets 10–14, elliptical or ovate-oblong, obtuse. Peduncles shorter than the leaves, 4–8-flowered. Flowers bluish-purple, $\frac{3}{4}$ in. long. Common N. and W.

XXII. LATHYRUS L.

Like *Vicia*, excepting that the leaflets are fewer and the style is bearded on the side toward the standard.

1. **L. maritimus** Bigelow. BEACH PEA. Perennial. Stem stout, 1–2 ft. high. Stipules broadly ovate and heart- or halberd-shaped, nearly as large as the 6–12 leaflets, of which the lower pair is the largest; tendrils pretty large. Flowers large, blue or purple. Seashores and beaches of the Great Lakes.

2. **L. palustris** L. WILD PEA. Stem frequently winged, slender, and climbing by delicate tendrils at the ends of the leaves. Stipules narrow and pointed; leaflets 4–8, narrowly oblong to linear, acute. Peduncles bearing 2–6 pretty large, drooping, blue, purple, and white flowers. Damp thickets and borders of swamps.

3. **L. venosus** Muhl. VEINY VETCH. Perennial. Stem stout, prominently angled, climbing or reclining, 2–5 ft. long. Leaves short-petioled; stipules large, lanceolate; leaflets 5–7 pairs, broadly ovate-obtuse, mucronate. Peduncles nearly as long as the leaves, many-flowered. Flowers purple, $\frac{3}{4}$ in. long. Calyx teeth very unequal. Pod linear, veined, 4–6-seeded. Shady banks and moist prairies.*

4. **L. odoratus** L. SWEET PEA. Annual. Stem roughish-hairy, it and the petioles winged. Leaflets only one pair, oval or oblong. Flowers large, 2 or 3 on the long peduncles, sweet-scented, white, rose color, purple, or variegated. Cultivated from Europe.

XXIII. PISUM L.

Climbing or prostrate herbs. Style enlarged above, grooved on the back, with soft-hairy down on the inner edge. Leaflets 1–3 pairs. Flowers and fruit much like those of *Lathyrus*.

1. **P. sativum** L. Common Pea. Annual. Smooth and covered with a bloom. Leaflets usually 2 pairs; tendrils branching; stipules large, ovate, rather heart-shaped at the base. Peduncle several-flowered. Flowers white, bluish, reddish, or variegated. Pods large; seeds globular or somewhat flattened and wrinkled. There are many varieties, differing greatly in size, of the plant and of the fruit. Cultivated from Europe (?).

XXIV. PHASEOLUS L.

Twining herbs. Leaves pinnate, of 3 leaflets. Flowers in axillary racemes. Calyx 5-toothed or 5-cleft, the two upper teeth often more united than the others. Keel of the corolla coiled in a spiral, together with the included stamens and style. Stamens diadelphous (9 and 1). Style bearded lengthwise on the upper side; stigma oblique or on the side of the style. Pod linear, 2-valved, several–many-seeded, tipped with the remains of the style.

1. **P. perennis** Walt. Wild Bean. Perennial, climbing high. Flowers small, purple. Pods curved, drooping, 4–6-seeded. Thickets.

2. **P. vulgaris** L. Common or Kidney Bean. Twiners (or some varieties low and branching). Racemes of white or purplish flowers shorter than the leaves. Pods straight or nearly so. Seeds not much flattened. Cultivated, probably from tropical America.

3. **P. multiflorus** Willd. Spanish Bean, Scarlet Runner. Stems twining high. Flowers large and showy, white, scarlet, or variegated; racemes longer than the leaves. The scarlet variety is the most commonly cultivated, for ornament. From tropical America.

48. GERANIACEÆ. Geranium Family

Herbs or small shrubs. Leaves simple, usually with glandular hairs which secrete an aromatic oil. Flowers bisexual, axillary and solitary or clustered, actinomorphic or nearly so, hypogynous, their parts in fives. Stamens 5 or 10, monadelphous at the base. Carpels 5, each 2-ovuled, splitting away with their long styles when ripe from a central axis and thus scattering the seeds.

I. GERANIUM L.

Herbs, rarely shrubs. Leaves with stipules, opposite or alternate, usually cut or lobed. Flowers actinomorphic on

1–2-flowered axillary peduncles. Sepals and petals 5. Stamens 10, ripening in 2 sets. Ovary 5-lobed, 5-beaked; stigmas 5.

1. G. maculatum L. WILD CRANE'S-BILL, WILD GERANIUM. Perennial, with an erect, hairy stem, 12–18 in. high. Leaves about 5-parted, marked with pale blotches, the basal leaves long-petioled. Flowers large (1 in. or more in diameter), light purple, somewhat corymbed. Petals entire, twice as long as the calyx, the claw bearded. Open woods and thickets; common.

2. G. Robertianum L. HERB ROBERT. Annual or biennial. Stems somewhat hairy, weak and spreading, reddish. Leaves of 5 leaflets, the latter once or twice pinnately cut, long-petioled. Flowers light purple, about $\frac{1}{2}$ in. in diameter, streaked with dark and light red. Claws of petals smooth. Damp woods and ravines E.

II. PELARGONIUM L'Her.

Perennial herbs or shrubs. Leaves with stipules, scented. Flowers much as in the preceding genus, but one of the sepals hollowed out below into a nectar-bearing tube extending down the pedicel. The 2 upper petals different in size or shape from the other 3. Cultivated from the Cape of Good Hope. [Most of the species are commonly, though not quite correctly, called "geraniums." Only a few of the commonest are here described.]

1. P. peltatum Ait. IVY GERANIUM. Stems somewhat prostrate and trailing. Leaves somewhat peltate, smooth or nearly so. Flowers pink or white.

2. P. zonale Willd. HORSESHOE GERANIUM. Stem erect, widely branched, woody below. Leaves alternate, opposite or sometimes in threes, round or kidney-shaped, palmately veined, crenate, downy, usually with a dark zone near the middle. Flowers in a long peduncled umbel, showy, red or white, often double. Numberless varieties in cultivation.

3. P. graveolens Ait. ROSE GERANIUM. Stem erect or ascending, densely downy, 1–3 ft. high. Leaves alternate, palmately lobed or divided, the lobes often finely dissected, rolled under at the edges. Flowers umbeled, small, light purple with darker veins; whole plant very fragrant. Common in cultivation.

4. P. odoratissimum Ait. NUTMEG GERANIUM. Branches crooked and straggling from a very short, moderately stout main stem. Leaves small, roundish and scalloped, covered with velvety down, very fragrant. Flowers white, inconspicuous, on short pedicels the petals hardly longer than the calyx.

49. OXALIDACEÆ. Wood Sorrel Family

Herbs or woody plants. Leaves compound. Flowers in fives, bisexual, actinomorphic, hypogynous. Stamens 10, somewhat monadelphous at the base. Ovary with several ovules in each cell. Fruit a capsule.

OXALIS L.

Acid herbs. Leaves basal or alternate, with or without stipules, usually of 3 leaflets, which droop at night. Sepals 5. Petals 5. Stamens 10. Ovary 5-lobed, 5-celled; styles 5.

1. **O. Acetosella** L. Wood Sorrel. Apparently stemless, from a creeping, scaly rootstock. Leaves all basal, long-petioled, of 3 inversely heart-shaped leaflets; scape slender, 2–5 in. high, 1-flowered. Flowers nearly 1 in. in diameter, white, veined with red or purple. Cold woods N.

2. **O. violacea** L. Violet Wood Sorrel. Perennial from a bulbous root, apparently stemless. Leaves long-petioled; leaflets inversely heart-shaped, sometimes slightly downy, often with a dark zone near the middle. Scapes usually longer than the petioles, umbellately 4–10-flowered; pedicels slender. Flowers violet-purple, nodding. Petals obtuse, 2–3 times as long as the sepals; scapes and petioles 4–5 in. long. Common in rich woods.*

3. **O. corniculata** L. Common Yellow Wood Sorrel. Probably flowering the first year but perennial, propagated by slender whitish rootstocks. Erect or decumbent, often sparsely hairy, usually 1 ft. or less in height. Stem leafy, the leaves often appearing whorled. Leaflets thin, green or purplish, often ciliate. Peduncles few-flowered, the ascending pedicels, clad with spreading hairs, forming unsymmetrical umbels or cymes at their summits. Flowers yellow, about $\frac{1}{3}$ in. in diameter. Pods hairy, columnar, grooved, often $\frac{1}{2}$ in. or more in length. A common weed in light soil.

50. TROPÆOLACEÆ. Indian Cress Family

Smooth and tender herbaceous plants, with biting juice, often climbing by the petioles of their simple leaves. Leaves alternate, without stipules. Peduncles axillary, 1-flowered. Sepals 3–5, the upper one with a long, distinct spur. Petals 1–5, hypogynous, not always all alike. Stamens 6–10, perigynous,

distinct. Ovary 1, 3-angled, made up of 3–5 1-ovuled carpels; style 1; stigmas 3–5. Fruit not opening.

TROPÆOLUM L.

Characteristics of the genus those of the family above given, together with the following:

Petals usually 5, clawed, the 2 upper inserted at the mouth of the spur and unlike the 3 lower ones. Stamens 8, ripening unequally, the filaments curved. Fruit 3-celled, 3-seeded. Cultivated from S.A. for the very showy flowers and the sharp-flavored fruits, which are often pickled.

1. **T. majus** L. COMMON NASTURTIUM. Climbing by the petioles 6–8 ft. (there is also a low variety which does not climb). Leaves roundish but more or less 6-angled, peltate, with the petiole attached near the middle. Flowers varying from almost white to nearly black, but commonly crimson, scarlet, or flame color.

51. LINACEÆ. FLAX FAMILY

Herbs, shrubs, or trees. Leaves usually alternate, simple, entire, sometimes with stipules. Flowers variously clustered. Sepals 5, distinct or united. Petals 5, hypogynous. Stamens 5, monadelphous below. Pod 8–10-seeded, with twice as many cells as there are styles.

LINUM L.

Herbs or small shrubs, with tough, fibrous bark. Leaves sessile. Flowers in corymbs or panicles. Sepals 5, entire. Petals 5, distinct or united below, falling in a few hours after expanding.

1. **L. usitatissimum** L. COMMON FLAX. Stem erect, with corymbed branches at the top. Leaves narrowly lanceolate. Flowers handsome, large, blue. Cultivated for the fiber. From Europe; introduced here to some extent.

2. **L. virginianum** L. WILD FLAX. Stem rather slender, erect and cylindrical; branches cylindrical. Leaves small, varying from oblong to lanceolate or spatulate, the lower often opposite. Flowers small, yellow. Capsules flattened at right angles to the pedicels. Dry woods and pastures.

52. RUTACEÆ. Rue Family

Shrubs or trees. Leaves alternate, compound, without stipules, marked with translucent dots. Flowers usually actinomorphic. Sepals and petals 3–5 or none; petals hypogynous or perigynous when present. Stamens as many or twice as many as the sepals, inserted on the glandular disk. Pistils 2–5, often partially united. Fruit a capsule, a key fruit, or in the important genus *Citrus* (orange, lemon, lime, etc., not here described) a leathery-skinned berry, the outer part of the skin containing many spherical oil cavities.*

I. XANTHOXYLUM

Trees or shrubs; bark, twigs, and petioles usually prickly; leaves odd-pinnate, marked with translucent dots. Flowers in axillary or terminal cymes or umbels, monœcious or diœcious. Sepals and petals 3–5 or none. Stamens 3–5, hypogynous. Pistils 2–5, distinct. Carpels 2-valved, 1–2-seeded; seeds smooth and shining.*

1. **X. americanum** Mill. Northern Prickly Ash, Toothache Tree. A prickly shrub, 8–12 ft. high, with aromatic bark. Leaves pinnately compound; leaflets ovate-oblong. Flowers small and greenish, in axillary umbels, appearing before the leaves. Petals 4–5. Pistils 3–5, the styles slender. Pods rather globose, somewhat more than $\frac{1}{8}$ in. in diameter, roughish, borne on a short stalk above the receptacle, with a strong scent of lemon and tasting at first aromatic, then burning. Rocky woods, ravines, and river banks.

II. PTELEA L.

Shrubs with smooth and bitter bark. Leaves with 3 leaflets. Flowers in terminal cymes, somewhat monœcious. Sepals 3–6, deciduous, much shorter than the petals. Stamens 4–5, longer than the petals and alternate with them. Pistillate flowers producing imperfect stamens. Ovary compressed, 2-celled. Fruit a 2-celled, 2-seeded, broadly winged key.*

1. **P. trifoliata** L. Hop Tree, Wafer Ash. A shrub 4–8 ft. high. Leaves long-petioled; leaflets oval or ovate, acute, obscurely serrate,

the lateral ones oblique. Cymes compound. Flowers greenish. Stamens mostly 4; filaments bearded; key about 1 in. in diameter; wing notched, strongly netted-veined. Rocky banks; often cultivated.*

53. POLYGALACEÆ. Polygala Family

Herbs or shrubs. Leaves alternate or nearly opposite, without stipules, simple. Flowers not actinomorphic. Sepals unequal, the 2 inner wing-shaped and petal-like. Petals 3–5, hypogynous, the 2 lateral ones often united with the hooded lower one into a tube, split open at the base behind. Stamens 8; filaments united into a split sheath, which is usually joined to the petals; anthers usually opening by pores. Ovary 2-celled, 2-ovuled. [A difficult family for the beginner.]

POLYGALA L.

Herbs or shrubs. Flowers racemed or spiked, some of them often cleistogamous. Petals united below to the stamen sheath. Anthers opening by transverse pores.

1. **P. paucifolia** Willd. Fringed Polygala, Babies' Toes, May Wings. A low perennial herb, with branches 3–4 in. high, from a slender, creeping rootstock. Lower leaves scattered, small and scale-like, the upper ones with petioles, crowded near the tips of the branches, ovate or nearly so. Flowers of two kinds, the cleistogamous whitish, fertile, borne underground along the rootstock, the terminal flowers large and showy (nearly an inch long), rose-purple, with a beautiful fringed crest. Woods, especially N. and E.

2. **P. Senega** L. Seneca Snakeroot. A perennial herb, with several erect stems arising from stout, hard, knotty rootstocks. Leaves lanceolate, oblong or lance-ovate, sessile. Flowers all alike, small, white, in solitary close spikes. Rocky woods.

54. EUPHORBIACEÆ. Spurge Family

Herbs, shrubs, or trees, usually with a milky, more or less acrid and sometimes poisonous juice. Flowers mostly apetalous, monœcious or diœcious (Fig. 23). Ovary usually 3-celled, with 1 or 2 ovules in each cell; stigmas as many as the cells

or twice as many. Fruit a 3-lobed capsule. Seeds containing fleshy or oily endosperm. Most of the family are natives of hot regions, many of them of peculiar aspect from their adaptation to life in dry climates. [The family is too difficult for the beginner in botany to determine many of its genera and species with certainty, but a few are described below.]

I. JATROPHA L.

Shrubs or herbs. Leaves alternate. Flowers monœcious, staminate and pistillate intermixed in the cymes, apetalous. Calyx large, white, 5-lobed, corolla-like. Stamens numerous, usually monadelphous. Ovary usually 3-celled, 3-seeded; styles 3, united at the base, several-parted.*

1. **J. stimulosa** Michx. SPURGE NETTLE. Perennial herbs armed with stinging hairs; stems erect, branched, bright green with white lines, 8–15 in. high. Leaves long-petioled, deeply palmately 3–5-lobed, the lobes irregularly cut and toothed, often mottled. Sepals white, spreading. Seeds oblong, smooth, mottled. In dry woods S.*

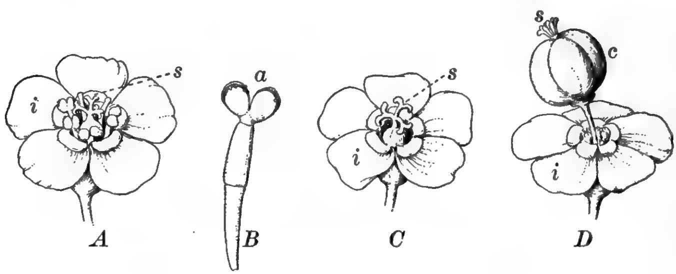


FIG. 23. *Euphorbia corollata*

A, flower cluster with involucre, the whole appearing like a single flower. *B*, a single staminate flower: *a*, anther. *C*, fertile flower, as seen after the removal of the sterile flowers. *D*, partly matured fruit: *i*, involucre; *s*, stigmas; *c*, capsule

II. EUPHORBIA L.

Herbs or shrubs, with milky juice, often poisonous. Flowers monœcious, inclosed in a 4–5-lobed involucre, which is often showy and resembles a calyx or corolla, usually bearing large

glands at its notches. Sterile flowers many, borne inside the involucre at its base (Fig. 23, *A*), each consisting only of a single stamen attached by a joint to a pedicel which looks like a filament. Fertile flower standing alone at the center of the involucre (Fig. 23, *C*) (soon pushed out by the growth of its pedicel), consisting only of a 3-lobed and 3-celled ovary, 3 2-cleft styles, and 6 stigmas. Pod 3-celled and 3-seeded.

A. *Cultivated shrubs.*

1. E. splendens Bojer. Crown of Thorns. An extremely prickly shrub, with many erect, few-leaved branches. Leaves obovate or obovate-spatulate, mucronate, entire, each with two very sharp prickles (longer than the petiole) as stipules. Peduncles long, sticky, each bearing 2–4 objects which appear to be showy scarlet flowers, but which are actually 2-bracted involucres containing the true flowers. Involucral scales somewhat kidney-shaped, mucronate. Flowering all the year round. Cultivated in greenhouses. From Mauritius.

B. *Herbs with rather showy white flower clusters.*

2. E. marginata Pursh: Snow on the Mountain. Annual. Stem stout, 1–3 ft. high. Leaves sessile, ovate, obovate or oblong, acute, $\frac{3}{4}$–3 in. long, the upper ones whorled and with white petal-like margins. Involucres 5-lobed in an umbel-like inflorescence with three forking rays. In dry soil W. and commonly cultivated.

3. E. corollata L. Flowering Spurge. Perennial. Stem erect, umbellately branched above, smooth or downy, 1–3 ft. high. Leaves of the stem alternate, those of the branches usually opposite or whorled, rather thick, oval to narrowly oblong, pale beneath, usually slightly downy. Flowering branches repeatedly forked; involucres terminal and in the forks of the branches, peduncled; glands 4–5, oblong, green; appendages white and petal-like, showy. Capsule erect, seed smooth or faintly pitted. Common in dry, open woods.

C. *Herbs: No. 4 a native species; No. 5 cultivated from Europe or escaping from gardens. Flower clusters in umbels, not white. Involucre 4- or 5-lobed, each lobe with a gland.*

4. E. dictyosperma Fisch. & Mey. Annual. Stem slender, 8–18 in. high, erect. Stem leaves oblong-spatulate to obovate, serrate; floral ones roundish-ovate, somewhat heart-shaped. Flower cluster a compound umbel, the rays once or twice 3-forked, then 2-forked. Seeds covered with a network. Prairies and roadsides.

5. **E. Cyparissias** L. CYPRESS SPURGE, CYPRESS, GRAVEYARD MOSS. A perennial, in dense clusters 6–12 in. high, from running rootstocks. Leaves much crowded, all sessile, the stem leaves linear, floral ones broadly heart-shaped. Flower cluster a simple, many-rayed umbel. Glands crescent-shaped. Cemeteries, roadsides, etc., escaped from cultivation; also cultivated in old gardens. From Europe.

55. ANACARDIACEÆ. SUMAC FAMILY

Trees or shrubs, with resinous, acrid, or milky sap. Leaves simple, of 3 leaflets or pinnately compound, alternate, without stipules. Flowers bisexual or unisexual, small. Calyx 3–5-parted, persistent. Petals 3–5 or wanting. Stamens as many as the sepals or sometimes twice as many, inserted in the base of the calyx, distinct. Ovary free, 1-celled; styles 1–3. Fruit a 1-seeded drupe.*

RHUS L.

Trees or shrubs. Leaves of 3 leaflets or odd-pinnate. Flowers in spikes or panicles. Calyx mostly 5-parted. Petals and stamens 5. Pistil 1, sessile; styles 3, terminal. Fruit small, smooth or downy.*

1. **R. typhina** L. STAG-HORN SUMAC. A small tree, 20–40 ft. high; branches and petioles closely velvety-hairy. Leaves odd-pinnate, leaflets 17–27, lanceolate-oblong, taper-pointed at the apex, very obtuse at the base, sharply serrate, smooth above, pale and downy beneath. Flowers somewhat monœcious, in dense terminal panicles. Fruit red, with crimson hairs. Dry hillsides N. and E.*

2. **R. glabra** L. SUMAC. A shrub or small tree, sometimes 25–30 ft. high; branches downy. Leaves odd-pinnate, main midrib downy and wing-margined; leaflets 9–21, ovate-lanceolate, acute at the apex, inequilateral, entire or slightly toothed, smooth and green above, pale and downy beneath. Panicle often large and spreading; flowers somewhat monœcious. Fruit red, hairy, acid. Open woods.*

3. **R. Vernix** L. POISON SUMAC, POISON DOGWOOD. A very smooth shrub with gray bark, 6–18 ft. high. Leaves large and glossy, with 7–13 obovate-oblong, entire leaflets. Flower clusters loosely flowered, axillary panicles. Fruit smooth, greenish-yellow. Swamps and wet openings in woods N. and E. Plant more poisonous than the following species.

4. **R. Toxicodendron** L. POISON VINE, POISON IVY, MERCURY, BLACK MERCURY. Stem a woody vine climbing high by aërial rootlets, or sometimes short and erect. Leaves petioled, of 3 leaflets, downy; leaflets ovate or oval, taper-pointed, entire or somewhat dentate, often angled or lobed. Flowers diœcious, in loose axillary panicles. Fruit nearly white, smooth. Common in open woods and along fences. Plant poisonous to the touch.*

56. AQUIFOLIACEÆ. HOLLY FAMILY

Trees or shrubs. Leaves simple, alternate, petioled; stipules small or wanting. Flowers small, greenish, clustered or solitary in the axils, usually diœcious. Calyx 4–9-parted. Petals 4–9, somewhat united at the base. Stamens inserted in the tube of the corolla and alternate with its lobes. Ovary free, 4–9-celled, with a single ovule in each cell. Fruit a berry-like drupe, 4–9-seeded.*

ILEX L.

Small trees or shrubs. Leaves usually leathery, often persistent and evergreen; stipules minute. Flowers axillary, 4–9-parted, the fertile often solitary and the staminate clustered. Fruit a drupe with 4–9 nutlets.*

1. **I. opaca** Ait. HOLLY. Trees with smooth, light-colored bark, and hard, very white wood; young twigs downy. Leaves leathery, oval or ovate, margin prickly-toothed, dark green and shining above, paler and sometimes slightly downy beneath. Peduncles short, bracted. Flowers 4-parted; staminate flowers in small cymes, the pistillate ones usually solitary. Fruit bright red. Damp, sandy soil E. and S.*

2. **I. decidua** Walt. DECIDUOUS HOLLY. Small trees; twigs smooth. Leaves thin, obovate, obtuse or sometimes acute at the apex, scalloped, smooth, deciduous. Flowers in sessile clusters, 4–6-parted. Fruits very numerous, bright red. On low ground S.*

3. **I. verticillata** Gray. BLACK ALDER, WINTERBERRY. A much-branched shrub 6–8 ft. high. Leaves thin, oval or obovate, taper-pointed, serrate, 1½–2 in. long. Flowers greenish-white, on very short peduncles. Fruit bright red, 1, 2, or 3 in a leaf axil, remaining long after the leaves have fallen. Swampy ground and damp woods and thickets.

57. CELASTRACEÆ. Wahoo Family

Trees or shrubs, sometimes climbing. Leaves simple, opposite or alternate. Flowers small, in cymes. Calyx small, 4–5-lobed, persistent. Petals 4–6, short. Stamens 4–6, alternate with the petals and inserted with them on a disk. Ovary sessile, 3–5-celled; style entire or 3–5-cleft; ovules 2 in each cell. Seeds usually covered with an appendage (aril) growing from the hilum.

I. EVONYMUS L.

Shrubs with 4-angled branches. Leaves opposite. Flowers in axillary, peduncled cymes, purplish or greenish, small. Sepals and petals 4–5, spreading. Stamens as many as the petals, short. Ovary 3–5-celled, with 2 ovules in each cell. Seeds inclosed in a red, fleshy pulp.*

1. **E. atropurpureus** Jacq. Wahoo. A tree-like shrub 10–15 ft. high. Leaves oval to ovate, taper-pointed, finely serrulate, minutely downy petioles $\frac{1}{2}$–$\frac{3}{4}$ in. long. Peduncles slender, 3-forked, several-flowered. Flower purplish. Capsule deeply 3–5-lobed, smooth. River banks.

2. **E. americanus** L. Strawberry Bush. A shrub 3–8 ft. high. Leaves short-petioled, ovate to ovate-lanceolate, acute or taper-pointed at the apex, finely serrulate, smooth or slightly hairy. Peduncles axillary, slender, 1–3-flowered. Flowers greenish. Capsule 3–5-angled, warty. In low, shady woods.

3. **E. obovatus** Nutt. Running Strawberry Bush. A low shrub, the trailing and rooting branches not usually rising more than 1 or 2 ft. from the ground. Leaves thin, obovate or oblong, mostly tapering to the base. Flowers and fruit nearly as in *E. americanus*. In damp woods.

II. CELASTRUS L.

A woody, twining shrub. Leaves alternate. Flowers diœcious or somewhat monœcious, small, greenish, clustered at the ends of the branches. Pod 3-celled, 3-valved, looking like an orange-colored berry, which on opening shows the scarlet arils of the seeds.

1. **C. scandens** L. Waxwork, Climbing Bittersweet. Climbing 10–15 ft. Leaves ovate-oblong, 2–4 in. long, finely serrate, taper-pointed. In thickets and along fences; also planted for the showy scarlet seeds, which retain their color for many months.

58. STAPHYLEACEÆ. Bladder Nut Family

Shrubs. Leaves pinnately compound, with stipules, and the leaflets with little individual stipules (stipels). Flowers regular and perfect. Calyx lobes 5. Petals 5, inserted in or around a saucer-shaped disk. Stamens 5, alternate with the petals, perigynous. Ovary 2–3-celled, with the carpels more or less distinct; ovules several; styles 2–3, somewhat united below. Fruit usually 1–few-seeded.

STAPHYLEA L.

Calyx deeply 5-parted, the lobes appearing like separate sepals, erect. Petals spatulate, borne on the rim of the thick disk. Pod large, papery, 3-celled, finally opening at the top. Seeds 1–4 in each cell, bony.

1. **S. trifolia** L. American Bladder Nut. A shrub 6–12 ft. high, with smooth, slender, greenish-striped, at length gray, branches. Leaves long-petioled, with 3 ovate, taper-pointed, finely serrate leaflets. Damp thickets.

59. ACERACEÆ. Maple Family

Trees or shrubs, with abundant, often sugary sap. Leaves opposite, simple and palmately lobed, or pinnate, without stipules. Flowers regular, mostly somewhat monœcious or diœcious, in axillary and terminal cymes or racemes. Calyx 4–9-parted. Petals as many as the lobes of the calyx or none. Stamens 4–12, hypogynous. Ovary 2-celled; styles 2. Fruit a double key.*

ACER L.

Characteristics of the genus as above given for the family.

1. **A. saccharum** Marsh. Sugar Maple. A large tree. Leaves simple, palmately lobed, truncate or heart-shaped at the base, lobes sinuate-toothed and acuminate, pale and slightly downy beneath. Flowers appearing with the leaves, on clustered drooping pedicels. Calyx bell-shaped, fringed. Petals none. Keys smooth, wings about

1–1½ in. long. In cold woods, more abundant northward. The sap of this tree is the principal source of maple sugar, and some forms of the tree produce the curled maple and bird's-eye maple used in cabinet making.*

2. A. saccharinum L. WHITE MAPLE, RIVER MAPLE. A tall tree with the main branches slender and rather erect. Leaves very deeply 5-lobed, with the notches rather acute, silvery-white, and when young downy on the lower surface, the divisions narrow, coarsely cut and toothed. Flowers greenish, in umbel-like clusters, appearing long before the leaves. Petals absent. Fruit woolly at first, then smooth, with diverging wings, the whole 2–3 in. long. Common on river banks S. and W., also planted for a shade tree, but not safe, as the branches are easily broken off by the wind.

3. A. rubrum L. RED MAPLE. A small tree with red or purple twigs. Leaves simple, broadly ovate, palmately 3–5-lobed or sometimes merely serrate or cut-toothed, taper-pointed at the apex, rounded or heart-shaped at the base, smooth or downy, becoming bright red in autumn. Flowers appearing before the leaves on erect, clustered pedicels. Petals red or yellow, oblong or linear. Fruiting pedicels elongated and drooping. Key red, smooth, wings about an inch long. Swamps and river banks E.*

4. A. Pseudo-Platanus L. SYCAMORE MAPLE. Easily recognized by its drooping clusters of rather large green flowers, which appear with the leaves. Cultivated from Europe.

5. A. platanoides L. NORWAY MAPLE. A large tree, with milky sap, which exudes from broken shoots or leafstalks in the spring. Cultivated from Europe; a very desirable shade tree.

6. A. Negundo L. BOX ELDER. A small tree. Leaves opposite, pinnately 3–5-foliate; leaflets ovate, lobed, toothed or entire, downy when young. Flowers diœcious, appearing from lateral buds before or with the leaves; the staminate on long and drooping pedicels, the pistillate in drooping racemes. Keys smooth, 1–1½ in. long. River banks. Often cultivated as a quick-growing shade tree.*

60. HIPPOCASTANACEÆ. BUCKEYE FAMILY

Trees or shrubs. Leaves opposite, long-petioled, palmately compound. Flowers showy, somewhat monœcious, in terminal panicles. Calyx 5-lobed, oblique. Petals 4–5, unequal. Stamens 5–8, hypogynous. Pistil 1; ovary 3-celled, 2 ovules in each cell; style slender. Fruit a 1–3-celled, leathery capsule, 1–3-seeded. Seeds with a large scar.*

ÆSCULUS L.

Characteristics of the genus as above given for the family.

1. **Æ. Hippocastanum** L. HORSE-CHESTNUT. A round-topped tree with frequently forking branches and stumpy twigs. Leaves very large, with 7 straight-veined leaflets. Flowers large and showy. Corolla open and spreading, of 5 white petals, spotted with purple and yellow. Stamens with long, curved filaments. Fruit large, covered with stout, soft prickles when young. Cultivated from Asia.

2. **Æ. glabra** Willd. OHIO BUCKEYE. A large tree, not unlike a horse-chestnut. Leaflets generally 5. Flowers small. Corolla of 4 upright, pale yellow petals. Stamens curved, about twice as long as the petals. Fruit prickly at first. River banks.

3. **Æ. octandra** Marsh. SWEET BUCKEYE. Varying in size from a low shrub to a tall tree. Leaves with 5–7 leaflets. Flowers in a short, dense panicle. Petals 4, in 2 unlike pairs, bending inward; blades of the longer pair very small. Fruit not prickly. Woods W. and S.

4. **Æ. Pavia** L. RED BUCKEYE. Shrubs. Stems erect, branched, 4–8 ft. high. Leaflets usually 5, lanceolate to narrowly oval, taper-pointed at both ends, finely serrate, smooth or nearly so. Flowers in dense, erect panicles, bright red. Stamens rather longer than the petals. Fruit nearly smooth. Common in open woods.*

61. BALSAMINACEÆ. BALSAM FAMILY

Tender, fleshy-stemmed, annual herbs. Leaves simple, without stipules. Flowers bisexual, zygomorphic. Sepals usually 3, the largest one with a spur. Petals 3. Stamens 5, distinct or nearly so. Ovary 5-celled, bursting when ripe into 5 valves.

IMPATIENS L.

Characteristics of the genus those above given for the family. Fruit a capsule (very fleshy in our species), which when ripe bursts open with considerable force, throwing the seeds about.

1. **I. pallida** Nutt. WILD BALSAM, LADY'S SLIPPER. Stem 3–5 ft. high, branching. Leaves oblong-ovate, 2–6 in. long, the lower often long-petioled, the upper nearly sessile. Peduncles axillary, 1–3 in. long, slender, 2–5-flowered. Flowers pale yellow, slightly dotted with brownish-red. Sac of the large sepal broader than it is long, ending in a recurved spur about ¼ in. long. Damp, shaded ground, not very common.

2. I. biflora Walt. Wild Balsam, Lady's Slipper, Jewelweed, Snapweed, Kicking Colt. Stem 2–4 ft. high, branching. Leaves rhombic-ovate, 1–4 in. long. Peduncles about 1 in. long, generally 2–3-flowered. Flowers orange color, with many pretty, large, reddish-brown spots. Sac longer than it is broad, ending in a recurved spur about ½ in. long. Damp, shaded ground, commoner than No. 1 and usually blossoming earlier.

62. RHAMNACEÆ. Buckthorn Family

Trees or shrubs. Leaves simple, often 3–5-nerved; stipules small. Flowers small, sometimes unisexual, green or yellow. Calyx 4–5-lobed. Petals 4, 5, or absent, inserted on a disk at the throat of the calyx, very small, hooded, usually with claws. Stamens 4–5, inserted with the petals and opposite them, often inclosed by the petals; filaments awl-shaped; anthers small, versatile. Ovary 3-celled, 3-ovuled.

I. BERCHEMIA Neck.

Shrubs; stems twining or erect. Leaves alternate, prominently pinnate-veined, stipules minute. Flowers in axillary or terminal panicles, or rarely solitary. Calyx tube hemispherical, 5-lobed. Petals 5, sessile, concave, as long as the calyx. Ovary 2-celled, half inferior; stigmas 2. Fruit an oval, 2-seeded drupe.*

1. B. scandens Trel. Supple Jack, Rattan Vine. Woody, often twining high; older bark yellowish, twigs purple, wood very tough. Leaves ovate or oval, acute or obtuse, cuspidate at the apex, rounded at the base, wavy on the margins, green above, pale beneath. Flowers in small panicles. Fruit purple. In moist woods and along streams S.*

II. RHAMNUS L.

Leaves alternate, deciduous. Flowers in small, axillary cymes, often unisexual. Petals 4–5 or wanting. Stamens 4 or 5, very short. Drupe, 2–4-seeded.

1. R. lanceolata Pursh. A tall shrub. Leaves with short petioles, taper-pointed or somewhat obtuse, very variable in size, smooth or nearly so above, more or less downy beneath, finely serrate. Flowers

2 or 3 together in the axils, greenish, about $\frac{1}{8}$ in. in diameter, usually diœcious, appearing at the same time as the leaves. Calyx 4-lobed. Petals 4. Stamens 4. Fruit black, about $\frac{1}{4}$ in. in diameter. Hills and river banks.

2. R. caroliniana Walt. CAROLINA BUCKTHORN. A small tree with black bark and very hard wood; twigs finely downy. Leaves alternate, prominently veined, elliptical to broadly oval, entire or obscurely serrate, smooth or sometimes downy below; petioles slender, downy. Flowers in axillary, peduncled umbels; petals minute. Fruit globose, $\frac{1}{3}$–$\frac{1}{2}$ in. in diameter, 3-seeded. Seeds smooth. On river banks.*

III. CEANOTHUS L.

Shrubs. Leaves alternate, petioled. Flowers bisexual, in terminal panicles or corymbs formed of little umbel-like clusters. Calyx tube top-shaped or hemispherical, with a 5-lobed border. Petals 5, with hoods, on slender claws. Stamens 5; filaments long and thread-like. Fruit dry, 3-lobed, splitting when ripe into 3 carpels.

1. C. americanus L. NEW JERSEY TEA, RED ROOT. Shrub, with many branching stems, 1–3 ft. high, from a deep red root. Leaves 1–3 in. long, ovate or nearly so, acute or taper-pointed at the tip, obtuse or somewhat heart-shaped at the base, downy beneath, serrate, 3-nerved. Flowers small, white.

2. C. ovatus Desf. SMALLER RED ROOT. Similar to *C. americanus* but usually smaller and nearly smooth. Leaves narrowly oval or elliptical-lanceolate, finely glandular-serrate, $\frac{1}{2}$–2 in. long. Dry rocks and prairies, especially S.W.

63. VITACEÆ. VINE FAMILY

Shrubs, with the stem swollen at the insertion of the petioles and climbing by tendrils borne opposite the leaves. Leaves alternate, with stipules simple or compound. Flowers small, greenish, generally in clusters, borne in similar positions to the tendrils, hypogynous or nearly so. Sepals, petals, and stamens 4–5. Carpels 2, each 2-ovuled. Calyx very small. Corolla deciduous, the petals often hooded. Stamens opposite the petals. A disk inside the calyx bears nectar and its lobes alternate with the stamens. Fruit a berry.

I. PSEDERA Neck. (PARTHENOCISSUS)

Woody vines, climbing by tendrils and rootlets. Leaves palmately compound. Flowers in compound cymes, perfect or somewhat monœcious. Petals 5, distinct, spreading; disk none. Stamens 5. Ovary 2-celled, 4-ovuled. Fruit a 1–4-seeded berry, not edible.*

1. P. quinquefolia Greene. WOODBINE, VIRGINIA CREEPER. Stem smooth. Leaflets dull green, paler below; tendrils 5–12-branched, most of the branches ending in disks which cling to supporting objects. Flowers panicled, the main branches of the cluster unequal. Fruit hardly fleshy. Thickets, common.

2. P. vitacea Greene. WOODBINE, VIRGINIA CREEPER. Stem smooth or slightly downy. Leaflets deep green above, not much paler below; tendrils 2–5-branched, the branches usually without disks at the tips. Flower cluster forking regularly, the main branches nearly equal. Fruit more fleshy than in No. 1. Moist woods and thickets in deep, rich soil; common.

3. P. tricuspidata Rehder. JAPANESE IVY, BOSTON IVY. A freely branching, hardy climber. Tendrils numerous, branching with closely adhesive disks. Leaves occasionally with 3 leaflets, but usually with only one, which is jointed with the main petiole and in autumn falls before the petiole; leaflet 3-lobed or only scalloped, roundish-ovate or heart-shaped, rather thick and shining. Cultivated from Japan.

II. VITIS L.

Climbing woody vines. Stems with enlarged joints, climbing by tendrils opposite some of the leaves. Leaves simple, palmately veined or lobed; stipules small, soon deciduous. Flowers mostly somewhat monœcious or diœcious. Petals often united at the apex and not expanding. Stamens inserted between the lobes of the disk. Ovary usually 2-celled, 4-ovuled. Fruit juicy, 1–4-seeded.*

1. V. labrusca L. FOX GRAPE. Stems climbing high, often 1 ft. or more in diameter; bark shreddy, coming off in long strips; young branches woolly. Leaves broadly heart-shaped, more or less deeply 3–5-lobed, mucronate-dentate, very woolly when young, becoming smooth above. Panicles of pistillate flowers compact, of staminate flowers looser. Fruit about $\frac{1}{2}$ in. in diameter, dark purple or sometimes nearly white. In rich woods E., S., and S.W. Many of the cultivated varieties, such as Concord, Niagara, etc., have been developed from this species.*

2. V. æstivalis Michx. SUMMER GRAPE. Stem climbing high; bark shreddy. Leaves broadly heart-shaped, 3–5-lobed, the lobes dentate, notches rounded, white-woolly when young, often nearly smooth when old; tendrils or panicles opposite 2 out of every 3 leaves, panicles long and slender. Fruit dark blue, small, very acid. In rich woods E. and S.*

3. V. cinerea Engelm. DOWNY GRAPE. Branchlets angular, covered with whitish or grayish down. Leaves entire or slightly 3-lobed, with whitish or grayish down, especially on the under side. Berries small, black, without bloom. S.W.

4. V. cordifolia Michx. FROST GRAPE, CHICKEN GRAPE. Leaves rather smooth, thin, and shining, either not lobed or somewhat 3-lobed, heart-shaped, with the notch at the base deep and acute, taper-pointed, with large, sharp teeth. Flower clusters large and loose. Grapes shining black, very sour, not ripening until after frosts; seeds 1 or 2, rather large. Moist thickets and banks of streams S.

5. V. vulpina L. RIVERSIDE OR SWEET-SCENTED GRAPE. Resembling *V. cordifolia*, but the leaves more shining and more commonly 3-lobed. Fruit bluish-black, with a bloom, moderately sweet, $\frac{1}{3}$ in. or more in diameter, beginning to ripen in July. Along ponds and streams, especially W. and S.W.

6. V. rotundifolia Michx. MUSCADINE GRAPE. Stem climbing high; joints short; bark not shreddy; wood very hard, often producing long, aërial roots. Leaves orbicular, heart-shaped at the base, coarsely toothed, nearly or quite smooth. Panicle small. Grapes few in a cluster, large. The original form of the Scuppernong grape. S.*

64. TILIACEÆ. LINDEN FAMILY

Trees or shrubs, rarely herbs. Leaves alternate, with stipules. Flowers bisexual in cymes, the latter usually in corymbs or panicles. Sepals 5. Petals 5 or fewer, or wanting. Stamens many, inserted on a swollen disk. Ovary 2–10-celled, with one or more ovules in each cell. Fruit 1–12-celled, dry or berry-like.

TILIA L.

Trees with rough gray bark on the trunk; bark of the twigs smooth, lead-colored; wood white and soft. Leaves cordate, usually inequilateral. Cymes axillary or terminal, peduncles adnate to a large, prominently veined, leaf-like bract. Flowers yellowish-white. Sepals 5. Petals 5. Stamens many, in 5

groups. Ovary 5-celled, with 2 ovules in each cell; stigma 5-lobed. Capsule 1-celled, 1–2-seeded; peduncle and bract deciduous with the matured fruit, the bract forming a wing by which the fruit is often carried to a considerable distance.*

1. **T. americana** L. BASSWOOD, WHITEWOOD. A large tree, sometimes 125 ft. high. Leaves larger than in No. 2 (2–5 in. wide), often unsymmetrical, heart-shaped or truncate at the base, sharply toothed. Floral bract often narrowed at the base. Fruit somewhat ovoid, $\frac{1}{3}$ in. or more in diameter. Common in rich woods; occurs farther N. than No. 2.

2. **T. Michauxii** Nutt. BASSWOOD. A tree of medium size. Leaves ovate, acuminate at the apex, obtuse and oblique at the base, mucronate-serrate, woolly on both sides or smooth above when old. Flowers fragrant; floral bract 2–3 in. long, usually rounded at the base. Fruit globose, about $\frac{1}{4}$ in. in diameter. In rich woods. Bees gather large quantities of nectar from the flowers.*

3. **T. heterophylla** Vent. WHITE BASSWOOD. A large tree. Leaves larger than in *T. americana* or *T. Michauxii*, often 6–8 in. long, smooth and bright green above, silvery-downy underneath. In wooded or mountainous districts.

4. **T. europæa** L. EUROPEAN LINDEN. A good-sized tree. Leaves roundish, obliquely heart-shaped, abruptly taper-pointed, finely toothed. Flowers differing from Nos. 1 and 2 in the absence of petal-like scales at the bases of the stamens. Cultivated from Europe.

65. MALVACEÆ. MALLOW FAMILY

Herbs or shrubs, with simple, alternate, palmately-veined leaves, with stipules. Flowers actinomorphic. Sepals 5, often surrounded by an involucre at the base. Petals 5. Stamens numerous, monadelphous. Pistils several, more or less distinct. Fruit a several-celled capsule or a collection of 1-seeded carpels.

I. ABUTILON Adans.

Calyx 5-cleft, the tube often angled. Styles 5–20, with knobbed stigmas. Carpels as many as the styles, arranged in a circle, each 1-celled, 3–6-seeded, and opening when ripe by 2 valves.

1. **A. striatum** Dicks. TASSEL TREE, FLOWERING MAPLE. A shrub 5–10 ft. high. Leaves maple-like. Flowers showy, solitary,

nodding on slender peduncles. Corolla not opening widely, orange, striped with reddish-brown veins. Column of stamens projecting beyond the corolla like a tassel. Cultivated in hothouses. From Brazil.

II. MALVASTRUM Gray

Calyx with an involucel of 2 or 3 bractlets or none. Petals notched at the end or entire. Styles 5 or more, with knobbed stigmas. Carpels not splitting open or somewhat 2-valved, falling from the axis when mature, tipped with a point or beak.

1. M. coccineum Gray. RED FALSE MALLOW. Perennial, 4–10 in. high, covered with a dense silvery down of star-shaped hairs. Leaves 3–5-parted. Flowers in short spikes or racemes. Petals red, much longer than the calyx. Carpels 10 or more, with a wrinkled network on the sides. Prairies W. and S.W.

III. MALVA L.

Calyx 5-cleft, with a small, 3-leaved involucel. Petals obcordate or truncate. Styles many, slender, with stigmas running down the sides. Carpels many, 1-seeded, arranged in a circle and separating from each other, but not opening when ripe.

1. M. rotundifolia L. COMMON MALLOW, CHEESES (from appearance of the unripe fruit). A common biennial or perennial weed, with nearly prostrate stems. Leaves long-petioled, round-kidney-shaped, with crenate margins. Flowers small, whitish, on long peduncles.

2. M. sylvestris L. HIGH MALLOW. Biennial or perennial. Stem erect, 2–3 ft. high. Leaves 5–7-lobed. Flowers purplish, larger than those of the preceding species.

IV. CALLIRHOË Nutt.

Calyx naked, or with a 3-leaved involucel at the base. Petals wedge-shaped, often toothed and fringed. Styles and stigmas as in *Malva*. Carpels 10–20, joined in a circle, 1-seeded, beaked at the tip.

1. C. alcæoides Gray. LIGHT POPPY MALLOW. Perennial. Stems rather slender, 8–20 in. high, covered with close-lying stiff hairs. Basal leaves triangular-heart-shaped, palmately lobed or incised;

stem leaves palmately divided. Involucel none. Flowers pink or white, about 1 in. in diameter. Carpels strongly wrinkled. In dry soil W. and S.W.

2. C. digitata Nutt. FRINGED POPPY MALLOW. Resembling *C. alcæoides.* Flowers $1\frac{1}{2}$–2 in. in diameter. Petals reddish-purple to white, fringed. In dry soil S.W.

3. C. involucrata Gray. PURPLE POPPY MALLOW. Perennial. Stems 1–2 ft. high, procumbent or ascending. Leaves round-heart-shaped, palmately lobed or cut. Involucel 3-leaved. Peduncles long, slender, and 1-flowered. Flowers reddish-purple, 1–$2\frac{1}{2}$ in. in diameter. Carpels with a wrinkled network. In dry soil W. and S.W.

66. HYPERICACEÆ. ST. JOHN'S-WORT FAMILY

Herbs, shrubs, or trees. Leaves opposite, often covered with translucent or dark dots, entire or with glandular teeth, without stipules. Flowers usually in terminal cymes. Sepals 5, rarely 4. Petals as many as the sepals, hypogynous. Stamens usually many, more or less grouped in bundles; anthers versatile. Pod 1-celled, with 2–5 parietal placentæ and the same number of styles, or else 3–7-celled, splitting along the partitions.

HYPERICUM L.

Herbs, shrubs, or small trees. Leaves sessile, often dotted. Flowers yellow, bisexual.

B. Fl. species 2 (*Sarothra*).

1. H. perforatum L. COMMON ST. JOHN'S-WORT. Perennial. Stem erect, 1–3 ft. high, 2-ridged, much branched. Leaves linear or oblong, obtuse, with translucent veins and dots. Cymes grouped in corymbs, many-flowered. Flowers 1 in. in diameter. Sepals acute. Petals much longer than the sepals, oblique at the tip and irregularly fringed. A common weed in meadows and pastures E. and N. Naturalized from Europe.

2. H. gentianoides BSP. ORANGE GRASS, PINEWEED. Low (4–9 in. high), slender annual, with erect, angled or almost winged, wiry stem and branches. Leaves minute awl-shaped scales. Corolla about $\frac{1}{4}$ in. in diameter, usually closing by or before midday. Sandy banks and roadsides.

67. VIOLACEÆ. Violet Family

Herbs, with simple, alternate leaves, with stipules. Calyx of 5 persistent sepals. Corolla of 5 petals, somewhat zygomorphic; one petal with a spur. Stamens 5, short, the filaments often united around the pistil (Fig. 24). Style generally club-shaped, with a one-sided stigma, with an opening leading to its interior. Pod 1-celled, splitting into 3 valves, each bearing a placenta. The seeds are often dispersed by the splitting of the elastic valves (Fig. 24).

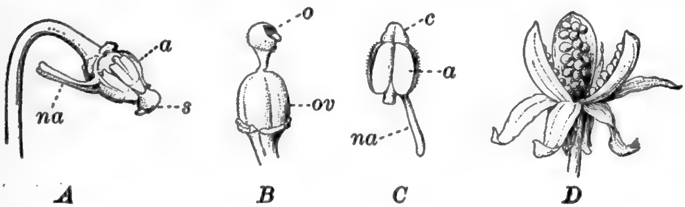


Fig. 24. *Viola tricolor*

A, stamens and pistil; *B*, pistil with stamens removed; *C*, stamen; *D*, pod split open. *a*, anther; *c*, connective; *na*, nectarial appendage of stamen; *o*, orifice in stigma; *ov*, ovary; *s*, stigma. (*A*, *B*, and *C* considerably magnified)

VIOLA L.

Sepals ear-like at the base. Some of the petals often bearded within, thus affording a foothold for bees, the lowest one with a spur at the base. Stamens not very much united, the two lowermost with spurs which reach down into the spur of the lowest petal. Many species bear inconspicuous apetalous flowers later than the showy ordinary ones, and produce most of their seed from these closed, self-fertilized flowers.

§ 1. *Apparently stemless perennials*

1. V. pedata L. Bird-Foot Violet, Horseshoe Violet, Sand Violet. Rootstock stout, upright, not scaly. Leaves roundish, all palmately 5–9-parted into linear or linear-lanceolate divisions. Flowers showy, about 1 in. broad, pale violet to whitish; petals not bearded. Dry fields and hillsides.

2. V. cucullata Ait. MARSH BLUE VIOLET. Leaves acute, except the earliest ones. Petal-bearing flowers violet blue, with a darker center; peduncles usually longer than the leaves, the spur-bearing petal smooth. Sepals narrowly lanceolate, with long ear-like appendages. Cleistogamous flowers borne on erect or ascending peduncles. Capsule not much longer than the sepals. Wet ground, common.

3. V. papilionacea Pursh. COMMON BLUE VIOLET, DOORYARD VIOLET. Plants usually strong and vigorous from a thick horizontal rootstock, usually smooth. Leaves bright green, cordate at the base, somewhat triangular or rounded and pointed. Scapes at the time of flowering longer than the leaves. Petals dark violet-purple, white or greenish-yellow at the base, the one with a spur often narrow and boat-shaped. Capsules from the cleistogamous flowers borne on horizontal peduncles and often underground, but rising as they mature. Very common about dwellings and gardens.

4. V. palmata L. EARLY BLUE VIOLET. Usually downy. Petioles much longer than the blades; leaves, except the earliest ones, cordate-ovate, with 5–9 variously toothed or cleft segments; the petioles and the veins of the under surface very hairy. Scapes not usually longer than the leaves. Sepals lanceolate, acute or taper-pointed. Petals violet-purple, occasionally pale. Capsules from the cleistogamous flowers borne on horizontal or deflexed peduncles. In dry, rich woodlands.

5. V. sororia Willd. WOOLLY BLUE VIOLET. In size and appearance much like No. 3. Leaves ascending, mostly ovate or roundish-ovate, pointed, cordate at the base, crenate, densely soft-hairy when young. Peduncles hairy; petals varying from violet to lavender. Cleistogamous flowers on short prostrate peduncles. Moist meadows and rich woods.

6. V. fimbriatula Sm. OVATE-LEAVED VIOLET. Rootstock usually erect, at length long and stout. Petioles generally shorter than the blades; leaves varying from ovate-lanceolate to oblong, usually slightly crenate, truncate or almost cordate at the base. Petals blue, bearded. Capsules of the cleistogamous flowers borne on erect peduncles. In dry woods.

§ 2. *Leafy-stemmed perennials*

7. V. pubescens Ait. DOWNY YELLOW VIOLET. Soft-downy, 6–12 in. high. Basal leaves ovate-kidney-shaped, soon withering; stem leaves broadly heart-shaped, toothed, pointed, with large stipules. Flowers yellow, somewhat purple-veined, with a short spur. In dry woods, common.

8. V. scabriuscula Schwein. SMOOTHISH YELLOW VIOLET. Like *V. pubescens*, but smaller, greener, and less downy. Stems decumbent or ascending. Basal leaves broadly ovate, usually persistent through

the flowering period. Flowers pale yellow, purple-veined. In moist woods and thickets.

9. V. canadensis L. CANADA VIOLET. Stems tufted, very leafy, smooth, 1 ft. or more high. Leaves heart-shaped, acute or taper-pointed, serrate ; stipules lanceolate, entire. Flowers large and handsome. Petals white or nearly so, inside, the upper ones usually violet-tinged beneath ; lateral petals bearded. In rich woods, especially of hilly regions.

10. V. striata Ait. STRIPED VIOLET. Similar to *V. canadensis*, but the stipules dentate, pinnately cut, or fringed. Petals cream-colored, white, or bluish, distinctly veined. Moist woods and thickets.

§ 3. *Leafy-stemmed, from an annual, biennial, or occasionally short-lived perennial root; stipules about as large as the blades of the leaves.*

11. V. tricolor L. PANSY, HEART'S-EASE. Stem branching, angular, hardly erect. Leaves variable, more or less ovate, crenate or crenate-serrate. Flowers large (often more than 1 in. across), flattish, short-spurred, exceedingly variable in color. Cultivated from Europe.

12. V. arvensis Murr. FIELD PANSY. Similar to *V. tricolor*, but the whole plant smaller and more slender. Leaves narrow, often lanceolate, the stipules dissected into narrow divisions. Petals all yellow, equaling or shorter than the slender, pointed sepals. Common in old fields. Naturalized from Europe.

13. V. Rafinesquii Greene. WILD PANSY. Annual, slender, often branching from the base. Leaves small, the earlier ones roundish, on slender petioles; the later ones obovate or narrower, tapering to the base. Flowers small, yellowish-white to bluish-white. Petals much longer than the linear sepals. Woods and fields.

68. PASSIFLORACEÆ. PASSION FLOWER FAMILY

Shrubs or herbs, climbing by axillary tendrils. Leaves alternate, simple, mostly 3-lobed. Flowers axillary, on jointed peduncles, solitary or few together, bisexual, actinomorphic, often showy. Calyx tube 4–5-lobed, persistent. Petals usually 5, inserted on the throat of the calyx tube, which is fringed with a crown of 1–3 rows of long and slender filaments. Stamens 5, their filaments united, and inclosing the stalk of the ovary. Styles 1–5; ovary with 3–5 parietal placentæ. Seeds numerous ; fruit fleshy.

PASSIFLORA L.

Characters of the family.

1. P. incarnata L. PASSION FLOWER. Perennial. Stem often 20–30 ft. long, somewhat angled or striate, smooth below, downy above. Leaves broadly heart-shaped, palmately 3–5-lobed; the lobes acute, finely serrate, usually heart-shaped at the base; petiole bearing 2 oval glands near its summit. Flowers 2–3 in. wide, solitary; peduncles 3-bracted, longer than the petioles; calyx lobes with a small horn-like appendage on the back near the apex, white within. Petals and crown purple and white. Fruit yellow, about the size and shape of a hen's egg, edible. Seeds with a pulpy aril. Common along fence rows and embankments S.*

2. P. lutea L. YELLOW PASSION FLOWER. Perennial. Stem slender, smooth, 6–10 ft. long. Leaves broadly heart-shaped, 3-lobed at the summit, entire, often mucronate; stipules small; petioles without glands. Peduncles longer than the leaves, usually in pairs. Flowers greenish-yellow, $\frac{1}{2}$–$\frac{3}{4}$ in. wide. Fruit purple, oval, $\frac{1}{2}$ in. long. Woods and thickets S.*

69. BEGONIACEÆ. BEGONIA FAMILY

Chiefly perennial herbs or low shrubs, with fleshy or very juicy stems. Leaves alternate, generally heart-shaped at the base, often very unsymmetrical; stipules deciduous. Flowers monœcious, in cymes or other clusters, on axillary peduncles. Stamens many (Fig. 25). Pistillate flowers with the floral envelopes borne on the ovary. Ovary 3-angled or 3-winged (Fig. 25), very many-seeded.

BEGONIA L.

Flowers with the calyx and corolla of the same color, staminate and pistillate ones both occurring in the same cluster. Sepals usually 2. Petals 2 or in the fertile flowers 3 or 4, sometimes wanting. Stamens many in a cluster, with short filaments. Styles of the fertile flowers 3, often with long, twisted stigmas (Fig. 25, *C*). The genus contains a great number of species and varieties, cultivated from tropical or subtropical regions, of which only a few of the commonest are here described.

1. B. Rex Putz. Herb, apparently stemless or nearly so, from a fleshy rootstock. Leaves large, taper-pointed, very unequally heart-shaped; the margin sinuous, often bristly-fringed; upper surface wholly silvery, or mottled silvery and dark green; lower surface green or reddish, or of both colors. Flowers few, large ($1\frac{1}{2}$–$1\frac{3}{4}$ in. in diameter), varying from yellow to pinkish. Cultivated from the Himalayas. Many varieties.

2. B. manicata Brongn. Herb, with a short and fleshy stem. Leaves very unevenly heart-shaped, taper-pointed; the margins bristly-fringed and sometimes with very remote teeth; upper surface dark green, lower surface and petioles partly covered with long fringed scales; stipules larger and fringed. Flowers flesh-colored, handsome, in a loose panicle borne on a long peduncle. Cultivated from Mexico.

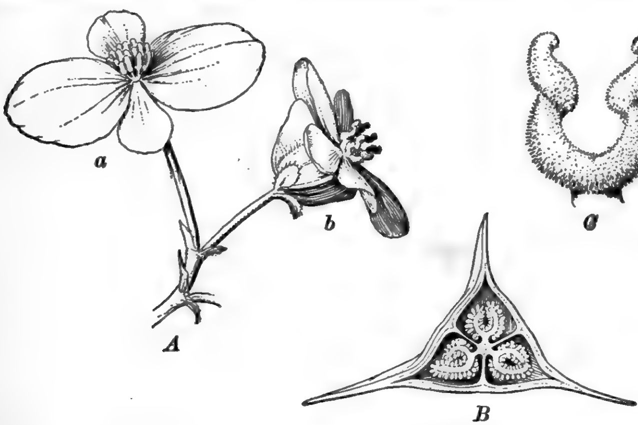


Fig. 25. Begonia flowers

A: *a*, staminate flower; *b*, pistillate flower. *B*, cross section of ovary; *C*, twisted stigmas, enlarged

3. B. coccinea Hook. Tall, 3–10 ft. high, somewhat shrubby, often with many erect, smooth stems from the same root. Leaves broadly and unevenly lanceolate or ovate-lanceolate, half heart-shaped or broadly one-eared at the base, acute, nearly or quite entire, smooth, dull green above, sometimes tinged with red below. Peduncles several–many-flowered, reddish, slender, somewhat nodding. Flowers showy, medium-sized, scarlet. Fruit showy, scarlet, very broadly winged. Cultivated from Peru. [Often called *B. rubra*.]

4. B. incarnata L. & O. Herbaceous or mainly so, rather tall (2–4 ft.), stems clustered, slightly reclining, hairy when young, at length smoother. Leaves broadly and very unequally ovate-lanceolate, tapering toward the tip but at the extremity somewhat blunt, half heart-shaped at the base, somewhat lobed and sinuate-toothed, rough-hairy above and below and on the petioles, dark green above with coppery streaks along the veins. Flowers on short peduncles, few, of medium size; beautiful rose-pink in the bud, becoming almost white; thickly covered outside with soft, moss-like hairs. Cultivated from Mexico. [Often called *B. metallica.*]

5. B. semperflorens L. & O. Stems smooth, herbaceous, rather fleshy, branching near the ground and reclining. Leaves obtuse or nearly so, broadly ovate, somewhat unevenly heart-shaped or tapering at the base, irregularly serrate or scalloped and wavy, smooth, dark green, and very glossy above; stipules rather large, nearly ovate. Flowers in small, axillary clusters near the top of the stem; whitish to crimson, about $1\frac{1}{4}$ in. in diameter. Ovary in fruit very broadly winged. An easily grown but homely species. Cultivated from S. Brazil.

70. CACTACEÆ. Cactus Family

Plants usually with very fleshy and much thickened, often globular or cylindrical, stems. Leaves usually wanting. Flowers sessile, solitary, often very showy. Perianth epigynous, consisting of several rows of sepals and petals. Stamens many, with slender filaments, borne on the inside of the perianth tube. Style 1; stigmas numerous; ovary 1-celled, many-ovuled. Fruit a many-seeded berry.

I. OPUNTIA L.

Stem composed of a series of flattened joints, which are usually leafless when full grown. Leaves very small, awl-shaped, spirally arranged, appearing on the young joints but soon dropping off, with barbed bristles and sometimes spines in their axils. Flowers yellow. Sepals and petals not much united into a tube. Fruit often eatable.

1. O. vulgaris Mill. Common Prickly Pear. Prostrate or nearly so, pale green. Leaves about $\frac{1}{6}$ in. long, rather scale-like; bristles many, with few or no spines. Flowers 2 in. or more in diameter,

with about 8 petals. Fruit about 1 in. long, crimson when ripe, eatable. Dry rocks and sandy ground, from Massachusetts south along the coast.

2. O. Rafinesquii Engelm. Prostrate, green. Leaves $\frac{1}{4}$–$\frac{1}{3}$ in. long, awl-shaped, spreading; bristles often intermixed with a few small spines and a larger one $\frac{3}{4}$–1 in. long. Flowers larger than in No. 1 and with 10–12 petals. Fruit about $1\frac{1}{2}$ in. long, much tapered at the base. In poor soil.

3. O. polyacantha Haw. Prostrate, light green. Leaves very small, with bristles and 5–10 spines in their axils. Flowers 2–3 in. in diameter. Fruit dry and spiny. Wisconsin, S. and W.

II. PHYLLOCACTUS Link.

Stems cylindrical when old, with long, flattened, fleshy but leaf-like, sinuate or serrate branches. Flowers nearly or quite regular, from the notches in the margins of the joints.

1. P. Ackermanni Solm. D. Flowers very showy, bright red. Perianth tube shorter than the petals. Sepals scattered, small and bract-like. Petals many, 2–3 in. long, widely spreading, somewhat channeled, sharp-pointed. Cultivated from Mexico.

III. CEREUS L.

Stem more or less prismatic but strongly ridged, with bundles of spines borne on the ridges; sometimes prostrate or trailing, sometimes erect, columnar, and 50 or 60 ft. high. Flowers usually showy, borne on the sides of the stem, generally with a rather long perianth tube, which is covered outside with scale-like sepals, usually with tufts of wool in their axils. Petals many, mostly long and spreading.

1. C. speciosus K. Sch. Stems 2–3 ft. high, with 3–4 broad-winged and sinuate ridges. Flowers open in the daytime and lasting several days, red or crimson, very showy. Petals longer than the tube, stamens white, drooping, very numerous. Commonly cultivated from Mexico.

2. C. grandiflorus Mill. NIGHT-BLOOMING CEREUS. Stems long, climbing by aërial roots, nearly cylindrical, but with 5 or more blunt angles. Flowers very showy, opening only for one night, wilting early in the morning, extremely fragrant. Sepals dull yellow. Petals pearly white, spreading, 6–8 in. long. Cultivated from Mexico.

71. ONAGRACEÆ. Evening Primrose Family

Herbs, rarely shrubs or trees. Leaves opposite or alternate, without stipules. Flowers actinomorphic. Limb of the calyx epigynous, 2–4-lobed. Petals 2–4, rarely wanting, quickly falling off. Stamens 1–8. Ovary usually 4-celled; style thread-like; stigma entire or 4-lobed; ovules 1 or more in the inner angle of each cell. Fruit a capsule, berry, or drupe. Seeds 1 or more, smooth or hairy.

I. ŒNOTHERA L.

Herbs, rarely shrubby. Leaves alternate. Flowers large, yellow, red, or purple. Calyx tube 4-angled. Petals 4. Stamens 8. Capsule usually 4-celled, many-seeded.

B. Fl. species 1 (*Onagra*); species 2, 3 (*Kneiffia*); species 4 (*Hartmannia*); species 5 (*Megapterium*).

1. **Œ. biennis** L. Common Evening Primrose. Annual or biennial. Erect and usually stout, 1–5 ft. high, stem usually simple, more or less downy and hairy. Leaves lanceolate, acute or taper-pointed, sessile or the lower ones petioled. Flowers bright yellow, 1–2 in. in diameter, opening in the evening. Pod oblong, narrowed above, erect, nearly cylindrical. In dry soil.

2. **Œ. pumila** L. Small Sundrops. Perennial. Stem erect, finely downy, 4–24 in. high. Leaves usually smooth, entire, obtuse or nearly so, the basal ones spatulate, those of the stem varying from oblanceolate to lanceolate. Spikes loose, nodding when young. Flowers $\frac{1}{3}$–1 in. in diameter. Pods slightly glandular-downy, club-shaped, $\frac{1}{4}$–$\frac{1}{2}$ in. long. In dry soil.

3. **Œ. fruticosa** L. Sundrops. Biennial or perennial. Stem erect, often rather stout, 1–3 ft. high, downy or sometimes smooth. Leaves lance-oblong, or in one variety linear or nearly so, usually minutely toothed. Racemes often corymbed. Flowers open in the daytime, showy, yellow, 1–2 in. in diameter. Pod nearly sessile, ellipsoidal, with prominent ribs and strong wings. Dry soil, common.

4. **Œ. speciosa** Nutt. Showy Primrose. Perennial. Stem downy, erect or somewhat decumbent, 6 in.–3 ft. high. Leaves broadly lanceolate to linear, sinuate-denticulate or sinuate-pinnatifid, 2–3 in. long. Flowers opening in the daytime, few, $1\frac{1}{2}$–$3\frac{1}{2}$ in. in diameter, white to pale pink. Pod strongly 8-ribbed. Prairies S.W.

5. Œ. missouriensis Sims. Perennial. Stems low, decumbent, with short, silky down. Leaves thick, from oval to linear, usually lanceolate, narrowed to a slender petiole, 2–6 in. long, entire or remotely toothed. Flowers axillary, yellow, 3–6 in. in diameter. Capsule orbicular, with broad wings. In dry soil S.W.

II. FUCHSIA L.

Herbs, shrubs, or trees. Leaves opposite or 3 in a whorl. Flowers showy. Calyx colored, tubular-funnel-shaped, the tube extending much beyond the ovary, the margin 4-lobed. Petals 4, borne in the throat of the calyx. Stamens 8, projecting outside the corolla. Capsule berry-like, ellipsoidal, 4-angled.

1. F. macrostemma R. & P. COMMON FUCHSIA, LADIES' EARDROPS. Smooth. Leaves slender-petioled, toothed. Flowers on long, drooping peduncles from the axils of the leaves. Calyx tube oblong or a short cylinder, not as long as its spreading lobes. Petals obovate and notched, wrapped spirally around the projecting filaments and style. Found in many varieties, sometimes the calyx white or nearly so and the petals dark or with dark calyx and light petals. Cultivated from Chile.

III. CIRCÆA L.

Slender, erect herbs, with creeping rootstocks. Stem simple. Leaves opposite, petioled. Flowers small, in terminal and lateral racemes. Calyx tube ovoid, the limb 2-parted, reflexed, deciduous. Petals 2, inversely heart-shaped, inserted with the 2 stamens under the margin of a disk which is borne on the pistil. Ovary 1–2-celled; style thread-like; stigma knobbed, 2-lobed; ovules, 1 in each cell. Fruit ovoid, not splitting open, covered with hooked bristles.

1. C. lutetiana L. ENCHANTER'S NIGHTSHADE. Stem 1–2 ft. high, glandular-downy. Leaves ovate, faintly toothed, long-petioled. Flowers $\frac{1}{8}$ in. in diameter, white or pink, on slender pedicels, jointed at the base. Damp, shaded places; very common.

72. ARALIACEÆ. GINSENG FAMILY

Herbs, shrubs, or trees. Leaves alternate, simple or compound; stipules united to the petiole or wanting. Flowers regular, in umbels or heads. Limb of the calyx epigynous,

very short. Petals 5, very deciduous. Stamens 5, filaments bent inward, anthers versatile. Ovary 2-celled or several-celled; styles or stigmas as many as the cells; ovules 1 in each cell. Fruit a drupe or berry. [The English ivy, an important member of the family, flowers too late for school study.]

ARALIA L.

Perennial plants, with pungent or spicy roots, bark, and fruit. Leaves once or more compound. Flowers more or less monœcious, white or greenish, in umbels. Drupe, berry-like.

1. **A. hispida** Vent. BRISTLY SARSAPARILLA, WILD ELDER. Stem 1–2 ft. high, rather shrubby below, with prickly bristles. Leaves once or twice pinnate; leaflets ovate, acute, cut-serrate, and often lobed. Peduncle bearing several umbels of cream-colored flowers, in a terminal corymb. Fruit blue-black. Dry fields and pastures E.

2. **A. nudicaulis** L. WILD SARSAPARILLA. Perennial herb. Roots very long, somewhat fleshy, aromatic; stem very short or none. Leaf solitary, from a sheathing base, petioled, 6–12 in. long; compound in threes, each division 3–5-pinnate; leaflets oval or ovate, taper-pointed, finely and sharply serrate, smooth above, often downy below. Scape nearly as long as the petiole, usually bearing 3 short, peduncled umbels. Flowers greenish. Styles distinct. Fruit globose, black. In rich woods.

73. UMBELLIFERÆ. PARSLEY FAMILY

Herbs, usually with hollow, grooved stems. Flowers small, generally in umbels. Limb of the calyx either wanting or present only as a 5-toothed rim or margin around the top of the ovary. Petals 5. Stamens 5, inserted on the disk, which is borne by the ovary (Fig. 26). Ovary 2-celled and 2-ovuled (Fig. 26), ripening into 2 akene-like carpels, which separate from each other. Each carpel bears 5 longitudinal ribs, in the furrows between which secondary ribs frequently occur. On a cross section of the fruit oil tubes are seen, traversing the interspaces between the ribs, and near the surface of the fruit (Fig. 26, *D*). The seeds contain a small embryo, inclosed in considerable endosperm. [The family is a difficult one,

since the flowers are so much alike that the species are distinguished from each other mainly by minute characteristics of the fruit.]

I. ERYNGIUM L.

Annual, biennial, or perennial herbs. Stems erect or creeping. Leaves simple, mostly linear and spiny-toothed. Flowers white or blue, in dense, bracted heads or spikes, flowers bracteolate. Calyx teeth rigid, persistent. Petals erect, pointed. Styles slender. Fruit top-shaped, scaly or granular; ribs wanting; oil tubes usually 5, minute.*

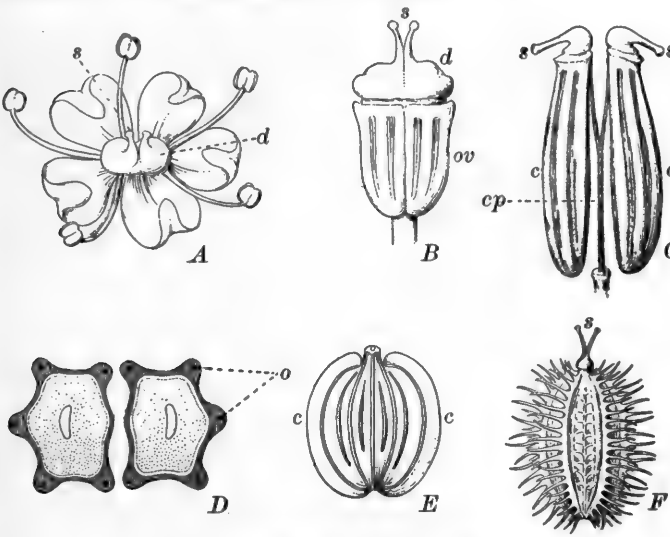


FIG. 26. Flower and fruit of *Umbelliferæ*

A–D, *Carum Carvi:* *A*, flower; *B*, partly matured pistil; *C*, mature fruit; *D*, cross section of fruit. *E*, fruit of parsnip; *F*, fruit of carrot. *c*, carpels; *cp*, carpophore, or stalk to which ripe carpels are attached; *d*, disk; *o*, oil tubes; *ov*, ovary; *s*, stigmas. (*A–D*, after Schnizlein; *E*, after Bischoff)

1. E. yuccifolium Michx. BUTTON SNAKEROOT, RATTLESNAKE MASTER. Perennial. Stem erect, branched above, striate, covered with a bloom, 2–3 ft. high. Leaves linear, often 2 ft. or more in

length, rigid, covered with a bloom, parallel-veined, fringed with white bristles. Bracts shorter than the heads, entire; bractlets similar but smaller. Flowers white. Fruit scaly. In damp soil.*

II. SANICULA L.

Slender, erect, perennial herbs. Rootstock short, stout, creeping. Leaves palmately cut. Umbels small, somewhat globular, irregularly compound; bracts leafy; bractlets few; flowers bisexual or staminate, greenish or yellowish. Calyx teeth as long as the small petals, sharp-pointed. Fruit ovoid, covered with hooked prickles, ribless, each carpel with 5 oil tubes.

1. S. marilandica L. SANICLE, BLACK SNAKEROOT. Perennial. Stem rather stout, 1–4 ft. high. Leaves 3–7-parted, the divisions irregularly serrate or dentate and often cut. Flowers bisexual and staminate, the latter in separate heads. Petals greenish-white, very small. Styles slender, recurved, and longer than the prickles of the fruit. Rich woods.

2. S. gregaria Bicknell. CLUSTERED SNAKEROOT. Stems generally clustered, 1–3 ft. high. Leaves 5-divided, obovate-wedge-shaped to lanceolate. Some of the staminate flowers in separate heads. Petals yellow, much longer than the calyx. Styles longer than the prickles of the fruit. Woods and thickets.

3. S. canadensis L. SHORT-STYLED SNAKEROOT. Leaves petioled, 3–5-divided. Staminate flowers never in separate heads. Styles shorter than the prickles of the fruit. In woodlands.

III. ERIGENIA Nutt.

A little smooth plant, with a slender, unbranched stem, from a deep, nearly globular tuber. Leaves 1 or 2, twice or thrice compound in threes. Flowers few, small, in an imperfect leafy-bracted umbel. Calyx teeth wanting. Petals obovate or spatulate. Fruit smooth, roundish, notched at both ends, the two carpels touching only at top and bottom, each with 5 slender ribs.

1. E. bulbosa Nutt. HARBINGER OF SPRING, TURKEY PEA, PEPPER-AND-SALT. Stem scape-like, with a leaf which forms an involucre to the flower cluster. Petals white, anthers brown-purple. A pretty, though inconspicuous plant; welcomed as one of the earliest spring flowers S.

IV. OSMORHIZA Raf. (WASHINGTONIA)

Perennials, springing from stout, aromatic roots. Leaves compound in threes. Flowers white, in compound umbels. Calyx teeth wanting. Fruit linear or nearly so, tapering at the base, with 5 equal bristly ribs, without oil tubes.

1. **O. Claytoni** Clarke. HAIRY SWEET CICELY. Rather stout and hairy, especially when young, 1½–3 ft. high. Lower leaves on long petioles, large, twice compound in threes, the divisions ovate or oval, cut-toothed; upper leaves nearly sessile, less compound. Umbels with long peduncles and spreading rays. Style and its enlarged base somewhat conical. Root nauseous. Rich woods.

2. **O. longistylis** DC. SMOOTH-LEAVED SWEET CICELY. Much like No. 1 in general appearance. Smooth or nearly so. Style rather thread-like. Root of a pleasant aromatic flavor (as is also the fruit). Woods.

Caution. So many plants of this family have actively poisonous roots and foliage that it is unsafe for any one but a botanist, who can distinguish the poisonous species from the harmless ones, to taste them.

V. CARUM L.

Herbs, with slender, smooth stems. Leaves pinnately compound, smooth. Umbels compound. Flowers white or yellowish. Calyx teeth minute. Fruit smooth, oblong or ovate, with thread-like ribs; oil tube single in the intervals between the ribs; base of the styles thickened into a conical mass.

1. **C. Carvi** L. CARAWAY. Perennial. Leaves large, with the leaflets cut into numerous thread-like divisions. Flowers white. Fruit aromatic, used somewhat in this country and more in N. Europe for flavoring cookies, bread, etc. Introduced from Europe.

VI. ZIZIA Koch.

Smooth perennials. Leaves generally as in *Thaspium.* Involucre wanting; involucels of small bractlets. Umbels compound. Flowers yellow. Calyx teeth prominent. Fruit more or less ovoid, smooth, with thread-like ribs; oil tubes large and solitary between the ribs, and a little one in each rib; the central fruit of each umbellet sessile.

1. **Z. aurea** Koch. MEADOW PARSNIP, GOLDEN ALEXANDERS. Smooth, stem erect, 1–2 ft. high. Basal leaves mostly heart-shaped and serrate; stem leaves usually once compound in threes. Flowers deep yellow. Fruit between globose and ovoid, about $\frac{1}{6}$ in. long; all the ribs generally winged. Woods and thickets.

VII. THASPIUM Nutt.

Perennial herbs. Stem erect. Leaves 1–2, compound in threes. Umbels compound; involucre and involucels usually wanting. Flowers yellow or purple. Calyx teeth small, acute. Fruit ovoid or oblong, somewhat laterally compressed; carpels smooth, strongly ribbed; oil tubes between the ribs.*

1. **T. barbinode** Nutt. HAIRY MEADOW PARSNIP. Stem erect, branching above, downy at the nodes, 2–7 ft. high. Leaves petioled, slightly downy; leaflets mostly thin, ovate, toothed, incised or lobed toward the apex, entire toward the base. Umbels long-peduncled, few-rayed. Fruit oblong; lateral and central ribs strongly winged. Along streams.*

VIII. LOMATIUM Raf.

Perennial herbs, appearing stemless. Roots thickened. Leaves dissected. Flowers white or yellow, in compound umbels, with no general involucre. Calyx teeth usually wanting. Fruit orbicular, oval or oblong, much flattened dorsally, the lateral ribs extended into broad wings; oil tubes 1–4 on the intervals between wings and 2–6 on the junctions of the carpels.

1. **L. orientale** Coult. & Rose. WHITE-FLOWERED PARSLEY. Downy, with peduncles 3–8 in. high. Leaves twice pinnate, the segments oblong or ovate, generally cut into rather obtuse linear or nearly linear lobes. Bracts of the involucels lanceolate, with thin membranous margins. Flowers white or pinkish. Fruit oval or round, notched at the base, smooth; oil tubes solitary in the intervals between ribs. Dry soil W.

2. **L. daucifolium** Coult. & Rose. CARROT-LEAVED PARSLEY. Leaves finely dissected into short linear or thread-like segments. Petals yellow. Fruit oval, with prominent dorsal ribs. Prairies W.

IX. PASTINACA L.

A tall, smooth biennial, with a stout, grooved stem. Leaves pinnate. Flowers yellow, in large umbels, with hardly any

involucre. Calyx teeth wanting. Fruit oval, very flat, with a thin wing; oil tubes single, running the whole length.

1. **P. sativa** L. Common Parsnip. Cultivated from Europe for its large, conical, sweet and edible roots. Also introduced in waste places.

X. HERACLEUM L.

A stout perennial, with the very large leaves compound in threes. Umbels large, compound, with the involucels many-leaved. Petals white, inversely heart-shaped, the outer ones usually 2-cleft and larger. Calyx with 5 small teeth. Fruit tipped with a thick, conical enlargement of the style, with three blunt ribs on the outer surface of each carpel and a large oil tube in each interval between the ribs. Seeds flat.

1. **H. lanatum** Michx. Cow Parsnip. Stem grooved and woolly, 4–8 ft. high. Leaflets petioled, broad, deeply and irregularly toothed.

XI. DAUCUS L.

Annual or biennial, bristly-hairy herbs. Leaves pinnately twice or more compound, the divisions slender. Umbels compound, many-rayed. Flowers small, white. Calyx teeth slender or wanting. Petals notched, the point bent inward, often unequal. Fruit ovoid or ellipsoid, with rows of spines.

1. **D. Carota** L. Common Carrot. Erect, 1–3 ft. high, with a conical, fleshy, orange-colored root. Lower and basal leaves 2–3-pinnate. Central flower of each umbel and sometimes of each umbellet larger and very dark purple, with the corolla irregular. Cultivated from Europe for the edible roots; also introduced in pastures and meadows and along roadsides E.

74. CORNACEÆ. Dogwood Family

Shrubs or trees, rarely herbs. Leaves opposite or alternate, without stipules. Flowers small, actinomorphic, variously clustered. Limb of the calyx epigynous, very short. Petals 4–5, borne on the margin of a disk on top of the ovary. Stamens 4–5, inserted with the petals. Ovary 1–4-celled, with one ovule in each cell; style 1. Fruit (in our species) a 1–2-celled and 1–2-seeded drupe.

I. CORNUS L.

Trees, shrubs, or herbs. Leaves usually opposite. Flowers in forking cymes, or in umbels or heads, each with an involucre, white or yellow. Calyx teeth 4. Petals 4. Stamens 4. Ovary 2-celled. Drupe ovoidal or ellipsoidal, the stone 2-celled.

1. C. canadensis L. DWARF CORNEL, BUNCHBERRY, PUDDING BERRY. Stem herbaceous, excepting at the base, low (3–9 in.), and unbranched. Rootstock rather woody, slender, and creeping. Leaves in what appears to be a whorl of 4 or 6 at the summit of the stem, sessile, ovate, oval or nearly so, acute at each end, entire, smooth or very slightly downy. Flower stalk slender, $\frac{1}{2}$–$1\frac{1}{2}$ in. long, with a whorl of 4–6 large, white, petal-like bracts, forming an involucre round the small head of greenish flowers; the head with its involucre appearing to others than botanists like a single flower. Fruit nearly spherical, scarlet, about $\frac{1}{4}$ in. in diameter, in a close cluster, sweet and eatable, though rather insipid. Damp woods, especially N.

2. C. florida L. FLOWERING DOGWOOD. Small trees; bark rough, black. Leaves opposite, petioled, ovate to ovate-lanceolate, entire, green and shining above, paler and often downy beneath. Flowers small, greenish, in heads which are subtended by 4 large, white or pink, inversely heart-shaped bracts, thickened and greenish at the notch. Fruit ovoid, bright red. In rich woods S. and E.*

3. C. circinata L'Her. ROUND-LEAVED DOGWOOD. A shrub 3–10 ft. high, with green, warty twigs. Leaves petioled, roundish-oval, contracted to an abrupt point, entire, usually rounded or truncate at the base, pale and soft-downy beneath. Flowers in flat cymes, $1\frac{1}{2}$–$2\frac{1}{2}$ in. in diameter. Fruit globose, light blue, $\frac{1}{4}$ in. or less in diameter. Thickets often in rocky soil N. and along Allegheny Mountains.

4. C. Amomum Mill. KINNIKINNIK. A shrub 6–10 ft. high; twigs purple, downy when young. Leaves opposite, petioled, ovate or oblong, taper-pointed, smooth above, silky-downy below. Flowers white, in rather close cymes. Fruit blue, stone somewhat oblique. In low woods.*

5. C. asperifolia Michx. ROUGH-LEAVED DOGWOOD. A shrub 8–12 ft. high; twigs slender, reddish-brown, often warty, densely downy when young. Leaves opposite, short-petioled, lance-ovate or oblong, acute or taper-pointed, with rough down above, downy-woolly below. Cymes flat, spreading, the peduncle and branches covered with rough down. Flowers white. Fruit white or pale blue, stone depressed-globose. In dry woods.*

6. C. stolonifera Michx. RED OSIER DOGWOOD. A shrub 3–15 ft. high, with smooth, reddish-purple bark on all the younger twigs; spreading by suckers from the base and therefore the stems usually clustered. Leaves on rather slender petioles, acute or taper-pointed, rounded or tapered at the base; covered, at least beneath, by very fine, closely appressed hairs. Fruit white or nearly so, globose, $\frac{1}{4}$ in. or more in diameter. Common in wet ground, especially N.

7. C. alternifolia L. f. ALTERNATE-LEAVED DOGWOOD. A shrub or small tree; twigs greenish, striped. Leaves alternate, often clustered at the ends of the twigs, long-petioled, oval, acute at the apex and often at the base, minutely toothed, pale and covered with fine, appressed hairs beneath. Cymes loose and open; flowers white. Fruit deep blue. Banks of streams.*

II. NYSSA L.

Trees or shrubs. Leaves alternate, petioled, entire or few-toothed. Flowers somewhat monœcious or diœcious, the staminate in many-flowered heads or cymes, the pistillate in small clusters or solitary. Calyx tube 5-toothed or truncate. Petals minute or wanting. Stamens 5–10. Ovary 1-celled, 1-ovuled; style long and recurved. Fruit a 1-seeded drupe.

1. N. sylvatica Marsh. BLACK GUM. A tree with widely spreading branches and dark, rough bark; wood light-colored, very tough; base of trunk often enlarged. Leaves often clustered at the ends of the twigs, oval or obovate, taper-pointed or obtuse at the apex, entire, smooth and shining above, downy beneath, becoming bright red in autumn. Staminate flowers in heads; pistillate flowers 3–10, in a long-peduncled cluster. Fruit ovoid, dark blue or nearly black, $\frac{1}{2}$ in. long; stone slightly ridged. In rich, wet soil S. and E.*

2. N. aquatica L. TUPELO. A large tree, similar to the preceding. Leaves long-petioled, oval or ovate, acute at each end, entire or coarsely toothed, the lower sometimes heart-shaped, smooth above, downy beneath, 4–8 in. long. Staminate flowers in heads; pistillate flowers on long peduncles, solitary. Fruit ovoid, dark blue; stone sharply ridged. In swamps S. and E.*

75. PYROLACEÆ. PYROLA FAMILY

Perennial herbs, evergreen or else pale and without chlorophyll. Petals usually free from each other and falling off separately after flowering. Stamens hypogynous, the anthers

without appendages and opening by pores or by a transverse slit. Fruit a capsule containing a great number of very small seeds.

I. CHIMAPHILA Pursh.

Low plants, nearly herbaceous, with reclining stems, from long, horizontal, underground shoots. Leaves opposite or whorled, leathery, shining, evergreen, on short petioles. Flowers fragrant, white or purplish, on a corymb or umbel which terminates the stem. Calyx 5-cleft or 5-parted, persistent. Petals 5, concave, roundish, spreading. Stamens 10, the filaments enlarged and downy in the middle, the anthers somewhat 4-celled, opening when mature by pores at the outer end. Style top-shaped, nearly buried in the top of the globular ovary. Capsule erect, 5-celled.

1. C. umbellata Nutt. PRINCE'S PINE, PIPSISSEWA. Branches leafy, 4–12 in. high. Leaves spatulate or wedge-oblanceolate, obtuse or nearly so, sharply serrate, very green and glossy. Flowers several, umbeled or somewhat corymbed, white or pinkish, the anthers violet. Dry woods, especially under pine trees.

2. C. maculata Pursh. SPOTTED WINTERGREEN. Much resembles No. 1, but has only scattered teeth on the leaves, which are mottled with white on the upper surface and are often broad or rounded at the base. Dry woods.

II. PYROLA L.

Biennial or perennial, almost woody herbs; rootstocks slender and creeping. Leaves mostly basal, with broad petioles, evergreen. Flowers in racemes, nodding, on a bracted scape. Sepals 5. Corolla usually globose, of 5 free or nearly free, roundish petals. Stamens 10, in pairs opposite the petals, hypogynous; anthers as in *Chimaphila*. Capsule globose, 5-celled, splitting into 5 valves, the latter usually with downy edges.

1. P. elliptica Nutt. SHIN LEAF. Scape 5–10 in. high. Leaf blades obovate-oval or elliptical, rather thin, dark green, faintly scalloped, almost always longer than their margined petioles. Flowers greenish-white, very fragrant. Rich, usually dry, woods, especially N.

2. P. americana Sweet. ROUND-LEAVED WINTERGREEN. Scape 6–20 in. high. Leaf blades roundish or oval, leathery, shining above,

faintly scalloped, often rounded at the base or almost heart-shaped, usually shorter than the slightly margined petioles. Flowers white, very fragrant. Varies greatly. Usually in dry woods N.

III. MONOTROPA L.

Leafless, simple, erect, white, brown, or red root parasites or saprophytes or fed by slender fungus threads which cluster on the roots. Stem scaly, the upper scales often passing into bracts. Flowers solitary or in spikes or racemes. Sepals or bracts 2–5, erect, deciduous. Petals 4 or 5, erect or spreading. Stamens 8 or 10, hypogynous, the filaments awl-shaped; anthers kidney-shaped. Ovary 4–5-celled; style simple; stigma disk-like, with 4–5 rays.

B.Fl. species 2 (*Hypopitys*).

1. **M. uniflora** L. Indian Pipe. Stem smooth, fleshy, 4–6 in. high. Bracts ovate or lanceolate. Flower single, tubular, $\frac{3}{4}$–1 in. long, inodorous. Stamens a little shorter than the petals. Capsule angled, $\frac{1}{2}$–$\frac{3}{4}$ in. long. Whole plant waxy-white, turning black in drying. In moist, shady woods N. and E.*

2. **M. Hypopitys** L. Pinesap. Stems single or clustered, white or reddish, 4–8 in. high. Bracts ovate-lanceolate. Flowers several, in a scaly raceme, fragrant, $\frac{1}{2}$–$\frac{3}{4}$ in. long. Capsule oval, $\frac{1}{4}$ in. long. In dry, shady woods, especially under oaks or pines.*

76. ERICACEÆ. Heath Family

Usually shrubs or slightly shrubby plants. Leaves simple, generally alternate. Corolla commonly actinomorphic, 4–5-cleft, sometimes choripetalous. Stamens hypogynous, distinct, as many or twice as many as the petals; the anthers mostly opening by a hole at the end. Ovary usually with as many cells as there are corolla lobes; style 1. Seeds small, with endosperm.

A

Shrubs or small trees. Calyx free from the ovary. Corolla hypogynous, usually sympetalous.

Shrubs or small trees, with showy flowers. Anthers not held down in pockets in the corolla. Rhododendron, I

Shrubs with showy flowers. Anthers at first held in pocket-like depressions in the corolla. Kalmia, II

Shrubs with small, mostly white, urn-shaped flowers. Lyonia, III

A prostrate plant, hardly at all shrubby. Leaves rather large, often 1½ in. wide, and veiny. Epigæa, IV

A trailing plant with small (about ¼ in. wide), thick, evergreen leaves. Arctostaphylos, V

B

Shrubs. Flowers epigynous; corolla sympetalous. Fruit a true berry or resembling one.

Fruit a berry-like drupe, with 10 nutlets which resemble seeds. Gaylussacia, VI

Fruit a berry with many small seeds. Vaccinium, VII

I. RHODODENDRON L.

Shrubs, often much branched. Leaves alternate, thin, deciduous. Flowers very showy, in terminal umbels, from scaly buds which became well developed the previous season. Calyx very small, 5-parted. Corolla bell-shaped, the tube long and slender, the limb spreading and somewhat one-sided. Stamens 5 or 10, declined; anthers awnless. Style long and slender, declined; stigma knobbed. Capsule oblong or linear, 5-celled, many-seeded; seeds very small, scale-like.

1. R. viscosum Torr. Swamp Honeysuckle, Swamp Pink. A shrub, 4–6 ft. high; branches hairy. Leaves obovate, leathery, mucronate at the apex, mostly smooth above, downy on the veins beneath; petioles very short. Flowers appearing later than the leaves, white, fragrant, 1½–2 in. long; tube long, glandular-viscid. Capsule erect, ½–⅔ in. long, bristly. In swamps.*

2. R. nudiflorum Torr. Wild Honeysuckle, Election Pink. A branching shrub, 4–6 ft. high; twigs smooth or with a few coarse hairs. Leaves obovate or oblong, ciliate-serrate, downy, becoming smooth above; petioles short. Flowers appearing with or before the leaves, pink or white, sometimes yellowish, fragrant, 1–2 in. wide, tube downy but not glandular. Capsule erect, linear-oblong, ⅔–¾ in. long. Swamps and banks of streams; flowers extremely variable in size and color.*

II. KALMIA L.

Erect and branching shrubs. Leaves alternate, opposite or in threes, entire, leathery, evergreen. Flowers showy, in corymbs, or 1–3 in the axils. Calyx 5-parted. Corolla flat-bell-shaped or wheel-shaped, 5-lobed. Stamens 10, the anthers placed in pouches in the corolla, filaments straightening elastically at maturity and so bringing the anthers in contact with any large insect-visitor. Style long and slender. Capsule globose, 5-celled, many-seeded.

1. **K. latifolia** L. CALICO BUSH, MOUNTAIN LAUREL. A shrub, 4–10 ft. high. Branches stout, smooth. Leaves mostly alternate, petioled, elliptical or oval, acute at each end, smooth and green on both sides. Corymbs terminal, compound. Flowers white to rose color, showy, 1 in. broad. Calyx and corolla glandular; pedicels long, slender, sticky-glandular, erect in fruit; calyx and style persistent. Shady banks on rocky or sandy soil.*

2. **K. angustifolia** L. SHEEP LAUREL, LAMBKILL. A shrub, 1–3 ft. high, with smooth, nearly erect branches. Leaves petioled, opposite or in threes, oblong, obtuse at both ends, dark green above, paler beneath. Corymbs lateral, glandular. Flowers purple or crimson, $\frac{1}{2}$–$\frac{1}{3}$ in. broad. Pedicels slender, recurved in fruit. Calyx downy, persistent. Style persistent; capsule depressed-globose. On hillsides; abundant northward.*

III. LYONIA Nutt.

Shrubs or small trees. Leaves alternate, persistent or falling late. Flowers mostly white, in panicles, racemes, or umbels. Calyx 5-parted; corolla urn-shaped. Stamens 10; filaments hairy, often with teeth or appendages; anthers oblong or ovoid. Capsule globose or nearly so, 5-angled. Seeds sawdust-like, with a loose outer coat.

B. Fl. species 1 (*Pieris*); species 2 (*Xolisma*).

1. **L. mariana** D. Don. STAGGERBUSH. A smooth shrub, 20–40 in. high. Leaves oval or oblong, smooth above, slightly downy on the veins beneath. Flowers nodding, on leafless shoots. Filaments with 2 teeth near the apex. Capsule ovoid-pyramidal, truncate at its apex. Low, sandy soil. Foliage said to be poisonous.

2. **L. ligustrina** DC. MALE BERRY. A minutely downy shrub, $1\frac{1}{2}$–10 ft. high. Leaves varying from obovate to ovate, finely serrate or entire. Racemes usually leafless, crowded in terminal panicles. Filaments flat, without appendages. Capsule globose. Moist thickets and swamps.

IV. EPIGÆA L.

Prostrate or trailing shrubs. Stems rusty-downy, 6–12 in. long. Leaves alternate, leathery, evergreen. Flowers in bracted, terminal, close racemes or clusters. Calyx 5-parted, persistent. Corolla salver-shaped, 5-lobed. Stamens 10, about the length of the corolla tube. Ovary 5-lobed; style columnar; stigma 5-lobed. Fruit a globose, hairy, 5-celled, many-seeded capsule.*

1. **E. repens** L. GROUND LAUREL, TRAILING ARBUTUS, MAYFLOWER. Stems creeping, the young twigs ascending. Leaves oval or somewhat heart-shaped, entire, netted-veined, smooth above, rough-hairy beneath; petioles short, rough-hairy. Racemes shorter than the leaves. Flowers white to bright pink, $\frac{1}{2}$ in. broad, very fragrant. In dry woods, often covering considerable areas.*

V. ARCTOSTAPHYLOS Adans.

Shrubs. Leaves alternate, evergreen. Flowers pinkish or nearly white, in terminal, bracted racemes. Calyx 4–5-parted, persistent. Corolla 4–5-lobed, the lobes recurved. Ovary 5–10-celled, each cell containing 1 ovule. Fruit a berry-like drupe, with 5–10 nutlets.

1. **A. Uva-ursi** Spreng. BEARBERRY. In trailing clumps, the branches 1–2 ft. high. Leaves evergreen, finely woolly, obovate or spatulate, entire, very leathery. Racemes few-flowered, very short. Corolla urn-shaped, the teeth hairy within. Berry red, $\frac{1}{4}$ in. in diameter. Rocks and dry hilltops, especially N.

VI. GAYLUSSACIA HBK.

Low, branching shrubs, mostly resinous-dotted. Leaves serrate or entire. Flowers small, white or pink, in lateral, bracted racemes, nodding; pedicels usually 2-bracteolate. Calyx tube short, obconic, the lobes persistent. Corolla ovoid to bell-shaped, 5-lobed, the lobes erect or recurved. Stamens equal, usually included; anthers awnless. Fruit a 10-seeded, berry-like drupe.*

1. **G. frondosa** T. & G. TANGLEBERRY, DANGLEBERRY. An erect shrub, 1–3 ft. high; branches spreading, slender, gray, slightly downy. Leaves entire, oblong or obovate, obtuse, thin, smooth and green above; paler, downy, and with resinous dots, beneath; petioles short.

Racemes few-flowered. Corolla small, greenish-pink, short-bell-shaped; bracts small, oblong, shorter than the pedicels. Berry depressed-globose, dark blue, with bloom, sweet, about ⅓ in. in diameter. On low ground.*

2. G. baccata K. Koch. HUCKLEBERRY. A much-branched, stiff shrub, 1–3 ft. high, slightly downy when young. Leaves oval or oblong, rarely obovate, obtuse or nearly so, entire, covered when young with little resinous particles. Flowers in short, one-sided racemes. Corolla at first conical-ovoid, becoming afterward nearly cylindrical, pink or reddish. Fruit (in the typical form) black, with no bloom, sweet; the seed-like nutlets rather large. Woods and pastures in sandy soil.

VII. VACCINIUM L.

Shrubs or small trees. Leaves entire or serrulate, often leathery and evergreen. Flowers terminal or lateral, clustered or solitary, nodding. Pedicels 2-bracteolate. Calyx tube globose or hemispherical, 4–5-lobed, persistent. Corolla urn-shaped, cylindrical or bell-shaped, 4–5-lobed. Stamens twice as many as the lobes of the corolla; anthers awned or awnless. Ovary 4–5-celled, each cell partially divided by a partition, which makes the ovary appear 8–10-celled; style slender; stigma simple. Fruit a many-seeded berry.*

B. Fl. species 1 (*Batodendron*); species 2 (*Polycodium*); species 6 (*Oxycoccus*).

1. V. arboreum Marsh. FARKLEBERRY. Tree-like, sometimes 30 ft. high; bark gray; twigs slender, smooth or downy. Leaves deciduous, ovate or oval, mucronate, entire or glandular-dentate, leathery, green above, often slightly downy beneath. Racemes with leaf-like bracts; pedicels slender, drooping. Corolla campanulate, white. Anthers included; style projecting. Berry globose, black, mealy, ripening in winter. Common in dry, open woods.*

2. V. stamineum L. DEERBERRY, SQUAW HUCKLEBERRY. An erect shrub, 3–10 ft. high; branches widely spreading, twigs smooth or minutely downy. Leaves deciduous, oval or oblong, acute or taper-pointed at the apex, obtuse or slightly heart-shaped at the base, firm, smooth, and green above, pale and slightly downy beneath, petioled. Racemes with leaf-like bracts. Flowers numerous, drooping, on jointed, slender pedicels. Corolla bell-shaped, purplish-green, 2-awned anthers and style projecting. Berry globose or pear-shaped, inedible. Dry woods.*

3. V. pennsylvanicum Lam. DWARF BLUEBERRY, LOW BLUEBERRY. Low (usually 6–12 in. high, sometimes 2 ft. high) and smooth, with

warty green branches. Leaves oblong or oblong-lanceolate, sharply serrate, with little bristle-pointed teeth, both sides smooth and shining except for down occasionally on the midrib and veins below, pointed at both ends. Flowers few in a cluster, longer than their minute pedicels. Corolla oblong, bell-shaped, a little narrowed at the throat, white or pinkish. Berry blue, with much bloom, ripening earlier than the other eatable species, sweeter than No. 5 but not so high-flavored. In dry or sandy soil, especially N.

4. V. vacillans Kalm. LATE LOW BLUEBERRY. A low, stiff, smooth shrub, 1–3 ft. high; branches yellowish-green. Leaves obovate or oval, pale or dull green, smooth beneath, entire or nearly so. Flowers greenish-yellow or somewhat pink. Berries late-ripening, blue, with some bloom, sweet. Dry, especially sandy, soil.

5. V. corymbosum L. HIGH-BUSH BLUEBERRY. An erect shrub, 6–12 ft. high; branches stiff, young twigs minutely warty. Leaves deciduous, oval to ovate-lanceolate, acute, margins bristly, serrulate, smooth or downy, short-petioled. Racemes numerous, appearing with or before the leaves. Bracts oval or oblong, deciduous. Flowers white or pink. Corolla almost as long as the pedicel, cylindrical. Berry globose, blue or black, flavor slightly acid, pleasant. Common in woods and thickets. Whole plant extremely variable.*

6. V. macrocarpon Ait. CRANBERRY. Stems creeping, thread-like, 1–3 ft. or more in length, the branches not quite erect, sometimes 8 in. high. Leaves usually oval or oblong, obtuse, thickish, evergreen, the younger ones with the margins somewhat rolled under. Flowers nodding. Petals strongly reflexed, deep rose-red inside at the base, pale pinkish or almost white at the tips. Stamens with the filaments hardly $\frac{1}{3}$ as long as the anthers. Fruit red or reddish-purple, ellipsoidal or nearly globose, very acid, much valued for sauce, pies, and jellies. Common in peat bogs and wet meadows N.

77. PRIMULACEÆ. PRIMROSE FAMILY

Herbs, with simple leaves, often most or all of them basal. Flowers bisexual and actinomorphic, generally sympetalous. Stamens commonly 5, inserted on the corolla, opposite its lobes. Pistil consisting of a single stigma and style and a (generally free) 1-celled ovary, with a free central placenta.

A

Leaves all basal.

(*a*) Segments of corolla not reflexed, throat open. Stamens included. Primula, I

(*b*) As in (*a*), but throat of corolla narrowed. Androsace, II

(*c*) Segments of corolla much reflexed. Stamens protruding. Dodecatheon, VIII

B

Stems leafy, at least near the summit.

(*a*) Corolla yellow. No sterile appendages alternating with the stamens. Lysimachia, III

(*b*) Corolla yellow. Sterile appendages alternating with the stamens. Steironema, IV

(*c*) Corolla white. Stems with leaves mostly whorled near the summit. Trientalis, V

(*d*) Corolla scarlet (sometimes white or blue). Stems low, leafy throughout. Anagallis, VI

(*e*) Corolla inconspicuous, pink. Stems leafy, very short. Centunculus, VII

I. PRIMULA L.

Low, perennial herbs, with much-veined basal leaves ; scapes each bearing an umbel of flowers, which are often showy. Calyx tubular, decidedly angled, 5-cleft. Corolla more or less salver-shaped, with the tube widened above the insertion of the stamens ; the 5 lobes of the limb often notched or cleft. Stamens 5, not protruding outside the corolla tube. Capsule egg-shaped, splitting at the top into 5 valves, each of which may divide in halves.

1. P. grandiflora Lam. TRUE PRIMROSE. Leaves spatulate or obovate-oblong. Flowers rising on separate slender pedicels from the leaf axils. Corolla originally pale yellow, but varying to white, red, and many intermediate shades, with a broad, flat limb. Cultivated from Europe.

2. P. sinensis Sabine. CHINESE PRIMROSE. A rather coarse, downy plant. Leaves round-heart-shaped, more or less lobed and cut, long-petioled. Flowers large, in umbels, usually rose color or white. Calyx large, inflated and conical. Cultivated as a house plant from China.

II. ANDROSACE L.

Small herbs, with clustered basal leaves. Flowers very small, solitary or umbeled. Calyx 5-cleft, with a short tube. Corolla salver- or funnel-shaped, contracted at the throat, its tube

shorter than the calyx. Stamens 5, perigynous, not protruding from the tube of the corolla. Capsule 5-valved, few–many-seeded.

1. **A. occidentalis** Pursh. Annual, smooth or nearly so. Scapes usually clustered, 1–3 in. high, erect or ascending. Lobes of the calyx becoming leafy. Corolla white, shorter than the calyx. In dry soil W.

III. LYSIMACHIA L.

Perennials, with opposite or whorled entire leaves, which are often dotted. Calyx 5–6-parted. Corolla wheel-shaped, with its divisions commonly nearly separate. Stamens generally somewhat monadelphous at the base.

B. Fl. species 4 (*Naumburgia*).

1. **L. quadrifolia** L. FOUR-LEAVED LOOSESTRIFE. Stem erect and simple, 1–2 ft. high, hairy. Leaves whorled, most frequently in fours, broadly lanceolate. Flowers small, axillary, and solitary, on long and slender peduncles. Damp or sandy soil.

2. **L. terrestris** BSP. BULB-BEARING LOOSESTRIFE. Stems 1–2 ft. high, finally branching, frequently producing bulblets in the leaf axils after flowering. Leaves abundant, generally opposite, narrowly lanceolate. Flowers small, pediceled, in a long, terminal raceme. Low or swampy ground.

3. **L. Nummularia** L. MONEYWORT. Stems creeping, smooth. Leaves small, round or nearly so. Flowers solitary in the leaf axils, yellow, ½–1 in. in diameter. Cultivated and escaping into moist ground. Introduced from Europe.

4. **L. thyrsiflora** L. TUFTED LOOSESTRIFE. Stem simple, erect, 1–2 ft. high. Leaves all opposite and lanceolate except the lower ones. Racemes spike-like, 1 in. or less long, borne in the leaf axils near the middle of the stem. Flowers small, light yellow with black spots. In swamps.

IV. STEIRONEMA Raf.

Perennial herbs. Leaves opposite or whorled, simple, entire. Flowers yellow, axillary or racemose, on slender peduncles. Calyx tube 5-parted, persistent. Corolla 5-parted, wheel-shaped, tube very short or none, the lobes denticulate at the apex, and in the bud each one inclosing a stamen. Stamens 5, distinct or slightly united at the base; sterile rudiments often alternating with them. Ovary globose; style slender. Fruit a globose, 5-valved, few- or many-seeded capsule.*

1. S. ciliatum Raf. FRINGED LOOSESTRIFE. Stems erect, slender, simple or branched, 1–3 ft. high. Leaves opposite, ovate to ovate-lanceolate, acute at the apex, rounded at the base; margins and petioles hairy-fringed. Flowers solitary on axillary peduncles, $\frac{3}{4}$–1 in. broad; petals broadly ovate or roundish, denticulate; calyx shorter than the capsule. Woods and thickets.*

2. S. lanceolatum Gray. LANCE-LEAVED LOOSESTRIFE. Stem erect, 6–24 in. high. Leaves varying from lanceolate to oblong and linear, petioled or almost sessile, acute or taper-pointed. Flowers $\frac{3}{8}$–$\frac{3}{4}$ in. in diameter. Capsule nearly as long as the segments of the calyx. In moist ground and thickets.

3. S. quadriflorum Hitchc. LINEAR-LEAVED LOOSESTRIFE. Stem erect, 4-sided, slender, 1–3 ft. high. Basal leaves oblong or linear-oblong, on slender petioles; stem leaves, all but the lowest, nearly or quite sessile, narrowly linear, 2–4 in. long, smooth and shining. Flowers about $\frac{3}{4}$ in. in diameter, often clustered in fours at the ends of the branches. Corolla lobes pointed. Along streams, especially N.W.

V. TRIENTALIS L.

Low, smooth, perennial herbs, with slender, erect, unbranched stems. Leaves lanceolate, ovate, or oblong, mostly in a whorl at the summit of the stem. Flowers one or few, terminal, on slender peduncles, small, white or pink. Sepals narrow and spreading. Corolla wheel-shaped, with usually 7 taper-pointed segments. Ovary globose; style thread-like. Capsule globose, many-seeded.

1. T. americana Pursh. STAR FLOWER, CHICKWEED WINTERGREEN. Spreading by long and slender rootstocks; branches erect, stem-like, 3–9 in. high. Leaves very thin, pale green, pointed at both ends. Flowers white. Capsules white, marked off into polygonal sections, each corresponding to 1 seed. Cold woods; common N.

VI. ANAGALLIS L.

Annual or perennial herbs. Stems erect or diffuse. Leaves opposite or whorled. Flowers axillary, peduncled. Calyx tube 5-parted, persistent. Corolla wheel-shaped, 5-parted, longer than the calyx. Stamens 5, inserted on the base of the corolla; filaments bearded. Ovary globose; style slender; stigma knobbed. Fruit a many-seeded capsule, the top coming off like a lid.*

1. A. arvensis L. Poor Man's Weatherglass, Pimpernel. Annual; stem spreading, widely branched, 4-angled, smooth, 4–12 in. long. Leaves opposite, sessile, ovate, black-dotted beneath. Flowers on peduncles longer than the leaves, nodding in fruit. Corolla fringed with glandular hairs, longer than the acute calyx lobes, bright red (sometimes white or blue), opening in sunshine. Capsule globose, tipped by the persistent style. Introduced, and common in fields and gardens.*

VII. CENTUNCULUS L.

Small annuals, with alternate entire leaves. Flowers axillary and solitary, inconspicuous. Calyx 4–5-parted. Corolla 4–5-cleft, shorter than the calyx, the tube urn-shaped. Stamens 4–5, perigynous, with short filaments. Capsule globose, many-seeded, the top falling off as a lid.

1. C. minimus L. Chaffweed, False Pimpernel. Stems 1–6 in. high. Leaves spatulate or obovate, with short petioles. Flowers small, pink, nearly sessile, parts of the perianth usually in fours. Moist soil W.

VIII. DODECATHEON L.

A smooth, perennial herb, with a cluster of oblong or spatulate basal leaves, fibrous roots, and an unbranched scape, leafless except for an involucre of small bracts at the summit, with a large umbel of showy, nodding flowers. Calyx deeply 5-cleft, with reflexed, lanceolate divisions. Tube of the corolla very short, the divisions of the 5-parted limb strongly reflexed. Filaments short, somewhat united at the base; anthers long, acute, and combining to form a conspicuous cone.

1. D. Meadia L. Shooting Star, Indian Chief. Corolla varying from rose color to white. In rich woods in most of the Middle and Southern states. Often cultivated.

78. EBENACEÆ. Ebony Family

Trees or shrubs. Leaves alternate, entire, pinnately veined, without stipules. Flowers often diœcious. Calyx free from the ovary, persistent. Stamens 2–4 times as many as the divisions of the corolla. Ovary 3–12-celled; ovules 1 or 2 in each cell. Fruit a berry. Mostly tropical plants.

DIOSPYROS L.

Flowers diœcious or somewhat monœcious, the staminate ones in cymes, the pistillate ones axillary and solitary. Calyx 4–6-lobed. Corolla 4–6-lobed. Stamens in the staminate flowers usually 16, in the pistillate ones 8, imperfect. Fruit large, with the persistent calyx attached to its base, 4–8-seeded.

1. **D. virginiana** L. PERSIMMON. Trees, with rough, black bark, and very hard wood. Leaves oval or ovate-oblong, acute or acuminate at the apex, rounded or slightly cordate at the base, entire and dark green, smooth above, pale and often downy beneath, short-petioled, deciduous. Flowers yellowish-white, the parts mostly in fours. Fruit globose, edible when ripe, very astringent when green; seeds large, compressed, often wanting. Fruit ripening late in the fall. Common in old fields and along roadsides S. and S.W.*

79. OLEACEÆ. OLIVE FAMILY

Shrubs or trees. Leaves opposite, simple or odd-pinnate, without stipules. Flowers usually in forking cymes, small, white, greenish or yellow, bisexual or unisexual. Calyx free from the ovary, 4-lobed or wanting. Corolla hypogynous, regular, 4-parted or of 4 separate petals, sometimes wanting. Stamens 2, borne on the petals or hypogynous. Ovary 2-celled. Fruit 1–2-celled, each cell 1-seeded, rarely 2-seeded (in *Forsythia* many-seeded).

I. FRAXINUS Tourn.

Deciduous trees. Flowers diœcious. Petals wanting (in our species). Stamens 2, hypogynous. Fruit a 1–2-celled key, each cell 1-seeded.

1. **F. americana** L. WHITE ASH. A large tree; bark rough, gray; wood hard, strong, elastic; twigs and petioles smooth. Leaflets usually 7, ovate to ovate-lanceolate, taper-pointed at the apex, rounded or obtuse at the base, entire or slightly serrate, smooth above, often downy beneath, short-stalked. Flowers mostly diœcious. Calyx of the pistillate flowers persistent. Key $1\frac{1}{2}$–2 in. long, winged only at the apex; wing spatulate or oblanceolate. In rich woods and swamps.*

2. **F. pennsylvanica** Marsh. RED ASH. A small tree; bark rough, dark gray; twigs and petioles densely velvety-downy. Leaflets 5–9, oblong-ovate to ovate-lanceolate, taper-pointed at the apex, narrowed

into a short stalk at the base, finely serrate, smooth above, velvety-downy beneath. Calyx of the pistillate flowers persistent. Key $1\frac{1}{2}$–2 in. long, the wing somewhat extended along the sides, oblanceolate or spatulate, often notched. Swamps and moist soil.*

3. F. caroliniana Mill. WATER ASH. A small tree; wood soft, light, and weak; twigs smooth or downy. Leaflets 5–7, ovate or elliptical, acute at the apex, acute or obtuse at the base, entire or slightly serrate, smooth or slightly downy, stalked. Flowers diœcious. Calyx persistent. Key often 3-angled or 3-winged, wings running nearly to the base, oblong or oval, pinnately veined. In swamps and wet soil.*

4. F. quadrangulata Michx. BLUE ASH. A large tree, with wood heavy, but not as tough as No. 1; the most vigorous twigs usually square. Leaflets 7–9, with short stalks, somewhat ovate or lanceolate, acute, sharply serrate. Fruit winged to the base, of nearly the same width throughout, narrowly oblong. Rich woods, especially W.

II. FORSYTHIA Vahl.

Shrubs. Leaves opposite or in threes, appearing later than the flowers, serrate. Calyx very short, deciduous. Corolla yellow, bell-shaped, its lobes long and slender. Stamens inserted on the base of the corolla tube. Pod 2-celled, many-seeded.

1. F. viridissima Lindl. A hardy shrub, with branches erect or nearly so. Leaves all simple, lance-oblong. Calyx lobes half as long as the tube of the corolla. Lobes of the corolla spreading, narrow-oblong. Style equal in length to the tube of the corolla. Cultivated from Asia.

2. F. suspensa Vahl. A hardy shrub, with drooping branches. Leaves broadly ovate, often some of them with 3 leaflets, the lateral leaflets small. Lobes of the corolla longer, broader, and more spreading than in No. 1. Style shorter than the tube of the corolla. Cultivated from Asia. Less common than No. 1; often trained over porches and arbors.

III. SYRINGA L.

Tall shrubs, forking frequently, from the failure of the terminal buds on most branches. Leaves simple, entire. Flowers in close, compound panicles. Calyx 4-toothed. Corolla salver-shaped, the tube long, the limb 4-lobed. Pod dry, flattened at right angles to the partition, 4-seeded.

1. S. vulgaris L. COMMON LILAC. A strong-growing, hardy bush. Leaves ovate, somewhat heart-shaped. Flowers sweet-scented, in very close, large clusters, lilac or white. Corolla lobes concave. Very commonly cultivated from eastern Europe.

2. S. persica L. Persian Lilac. A more slender and less branched shrub than No. 1. Leaves lance-ovate, somewhat narrowed or tapering at the base. Flowers in rather loose clusters, not very sweet-scented, pale lilac or white. Corolla lobes ovate, somewhat bent inward. Pods linear. Cultivated from western Asia, less common than No. 1.

IV. CHIONANTHUS L.

Shrubs or small trees. Leaves simple, opposite, entire, petioled, deciduous. Flowers in panicles borne on wood of the previous season. Calyx small, 4-cleft, persistent. Corolla wheel-shaped, 4-parted, the lobes long and linear. Stamens 2–4, included, inserted on the base of the corolla. Style short; stigma 2-lobed. Fruit a 1-seeded drupe.*

1. C. virginica L. Fringe Tree, Old Man's Beard. A small tree, with smooth, light gray bark and spreading branches. Leaves oval to oblong, acute or obtuse at each end, smooth or slightly downy. Panicles large and loose, leafy-bracted, appearing with the leaves. Flowers on slender, drooping pedicels. Petals 1 in. or more in length. Fruit ovoid, purple, $\frac{1}{2}$–$\frac{2}{3}$ in. long. Along streams, usually on light soil.*

V. LIGUSTRUM L.

Shrubs. Leaves simple, opposite, entire, deciduous or sometimes persistent. Flowers in terminal panicles or similar clusters, white, small. Calyx minutely 4-toothed or truncate. Corolla funnel form, 4-lobed. Stamens 2, short, inserted in the tube of the corolla. Ovary free, 2-celled, 2 ovules in each cell; style short. Fruit a 1–4-seeded, globose berry.*

1. L. vulgare L. Privet. A branching shrub, 4–10 ft. high; branches long and slender. Leaves somewhat leathery, lanceolate to obovate, short-petioled, tardily deciduous. Panicles dense, minutely downy. Flowers $\frac{1}{4}$ in. wide, fragrant. Stamens included. Berries black. Introduced from Europe and used largely for hedges.*

80. GENTIANACEÆ. Gentian Family

Annual or perennial herbs. Leaves entire, usually opposite, sometimes alternate, without stipules. Flowers actinomorphic, solitary or in cymes. Calyx hypogynous, 4–8-toothed or lobed. Corolla hypogynous, wheel-, bell-, or funnel-shaped,

4–8-lobed. Stamens 4–8, inserted on the corolla tube; filaments thread-shaped; anthers facing inwards. Ovary 1–2-celled; ovules many, on 2 opposite placentas. Capsule 1-celled or partially 2-celled, 2-valved, many-seeded. [The best known genus, *Gentiana,* consists mainly of autumn-flowering species.]

I. OBOLARIA L.

A low, smooth, purplish-green perennial. Flowers axillary and terminal. Calyx of 2 distinct, spatulate, bract-like sepals. Corolla tubular-bell-shaped, 4-lobed. Stamens short, inserted at the notches of the corolla. Style short; stigma 2-lipped. Capsule ovoid, more or less 2–4-celled; seeds very minute and numerous.

1. O. virginica L. Pennywort. Stem 3–8 in. high, often several from the same root. Leaves somewhat fleshy, wedge-obovate or somewhat diamond-shaped, often truncate, sessile. Flowers opposite or terminal in threes, nearly sessile. Corolla pale purple or nearly white. Rich woodlands, among dead leaves.

II. MENYANTHES L.

Perennial, scape-bearing marsh herbs. Rootstock creeping. Leaves of 3 leaflets. Flowers racemed. Calyx 5-parted. Corolla fleshy, funnel-shaped, the limb 5-parted. Stamens 5, inserted on the corolla tube. Disk of 5 hypogynous glands. Ovary 1-celled; style thread-shaped; stigma 2-lobed. Capsule globose, many-seeded.

1. M. trifoliata L. Buck Bean, Marsh Trefoil. Rootstocks stout and matted. Leaflets obtuse, entire. Flowers $\frac{2}{3}$ in. in diameter, white or pinkish. Bogs, especially N.

81. APOCYNACEÆ. Dogbane Family

Trees, shrubs, or herbs, with milky juice, often climbing. Leaves usually opposite, rarely whorled, entire, nearly or quite without stipules. Flowers actinomorphic, solitary or in cymes. Calyx 4–5-cleft. Corolla hypogynous, funnel-, salver-, or bell-shaped, sometimes with scales in the throat. Stamens 4–5, borne on the corolla tube or throat; filaments very short;

anthers somewhat attached to the stigma. Ovary of 2 carpels, free or somewhat united; style short; stigma entire or 2-cleft. Fruit of 2 many-seeded pods (in the genera here described).

I. AMSONIA Walt.

Perennial herbs. Stems erect, branched. Leaves alternate. Flowers in terminal panicles. Calyx small, 5-parted. Corolla small, pale blue, funnel- or salver-form, downy within. Stamens inserted above the middle of the tube, included. Ovary of 2 carpels, united at the top by the slender style; stigma globose, surrounded by a cup-shaped appendage. Fruit 2 slender, erect, many-seeded follicles; seeds without tufts of hairs.*

1. **A. Tabernæmontana** Walt. AMSONIA. Stem smooth and glabrous, branched above, 2–3 ft. high. Leaves lanceolate, entire, acuminate at the apex, acute at the base, smooth above, with a bloom or slightly downy beneath, short-petioled. Flowers numerous, on bracted pedicels. Corolla tube slender, smooth or sometimes downy above; the lobes narrow, as long as the tube. Follicles slender, spreading, 4–6 in. long; seeds downy. Swamps and wet ground S.*

II. VINCA L.

Perennial herbs or small, slender shrubs; juice not perceptibly milky. Leaves evergreen. Flowers solitary, white, blue, or purple. Calyx 5-parted; lobes taper-pointed, glandular inside at the base. Corolla salver-shaped, thickened at the throat, 5-lobed. Stamens 5, inserted on the upper or middle part of the corolla tube. Ovary of 2 carpels. Pods 2, slender, cylindrical, many-seeded.

1. **V. minor** L. PERIWINKLE. Stem slender, trailing, often rooting at the nodes, 1–3 ft. long. Leaves ovate, acute at the apex, short-petioled, bright green. Flowers axillary, solitary, 1 in. wide. Calyx with linear lobes nearly as long as the inflated tube of the blue corolla. Matured pods slender, slightly divergent. Introduced from Europe and common in gardens.*

III. APOCYNUM L.

Perennial herbs. Stems with very tough bark, branched above. Leaves opposite, entire. Flowers in terminal and axillary bracted cymes. Calyx small, 5-parted, lobes acute.

Corolla bell-shaped, 5-lobed, with a small, scale-like appendage at the base of each lobe. Stamens 5, distinct, inserted on the base of the corolla tube. Ovaries 2, distinct, united by the styles; stigma obtuse, 2-lobed. Pods long, slender, many-seeded; seeds with a tuft of hairs.*

1. A. androsæmifolium L. DOGBANE. Plant 2–3 ft. high, usually smooth, purplish, the branches spreading and forking. Leaves 2–3 in. long, acute, mucronate; petioles about ¼ in. long. Cymes mostly terminal, few-flowered. Calyx teeth lance-ovate, about half as long as the corolla tube. Corolla pale red or whitish, its lobes recurved. Pods stouter than in No. 2. Roadsides and clearings; common.

2. A. cannabinum L. INDIAN HEMP. Stem erect, smooth, with numerous erect or ascending branches. Leaves oval to oblong, mucronate at the apex, rounded at the base, downy beneath, short-petioled. Cymes terminal, compact, shorter than the leaves. Flowers are on short, bracted pedicels, greenish-white, about ¼ in. broad. Calyx lobes lanceolate, nearly as long as the tube of the corolla. Corolla lobes erect. Pods very slender, tapering, 3–4 in. long. Along fences and in thickets.*

IV. NERIUM L.

Shrubs. Leaves mostly whorled in threes. Flowers in terminal cymes. Calyx small, lobes acute. Corolla salverform, the throat of the tube crowned with cleft or cut-fringed scales. Stamens 5, short, included; anthers tipped with a hairy bristle. Ovary of 2 carpels; style short. Pods erect; seeds with a tuft of hairs.*

1. N. Oleander L. OLEANDER. Stem erect, diffusely branched from below, 4–10 ft. high. Leaves narrowly elliptical, acute at each end, thick and leathery, short-petioled. Flowers showy, in large clusters, red or white, often double; scales of the crown 3–4-pointed unequal teeth. Pods spindle-shaped, 3–4 in. long. Introduced from Palestine. Common in cultivation.*

82. ASCLEPIADACEÆ. MILKWEED FAMILY

Shrubs or herbs, often twining; juice usually milky. Leaves generally opposite or whorled, entire, without stipules. Flowers regular. Calyx 5-parted. Corolla 5-parted. Stamens 5; the filaments usually united around the styles, often with

hood-like appendages, each with an incurved horn borne on the stamen tube and forming a crown around the stigma (Fig. 27, *A*); anthers pressing against the lobes of the stigma; the pollen clinging together in tough, waxy or fine-grained

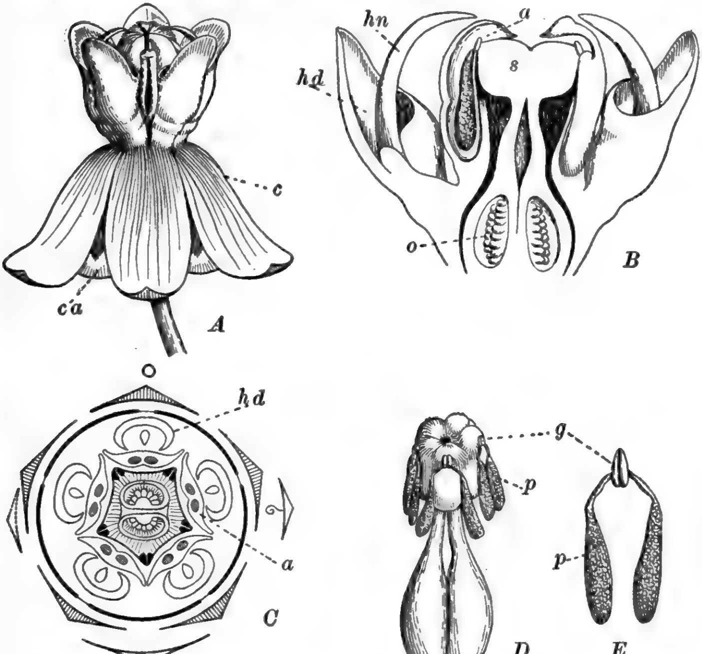


FIG. 27. Flower of *Asclepias syriaca*

A, entire flower; *B*, vertical section; *C*, diagram; *D*, details of pollen-masses and glands. *ca*, calyx; *c*, corolla; *hd*, hood; *hn*, horn; *a*, anther; *s*, stigma; *o*, ovary; *g*, gland; *p*, pollen-mass. (All considerably enlarged.)

masses. Ovary free from the calyx tube, of 2 carpels, more or less united below but unconnected above; styles 2; stigmas 5-angled; ovules several–many. Fruit consisting of 1 or 2 pods. The flowers are very highly specialized for pollination by insects (see below, under *Asclepias*).

I. ASCLEPIODORA Gray.

Plants much like *Asclepias,* but the hoods without horns. Lobes of the corolla ascending or spreading.

1. **A. viridis** Gray. GREEN MILKWEED. Stems about 1 ft. high, nearly smooth. Leaves alternate, short-petioled, oblong to ovate-lanceolate. Umbels clustered. Flowers about 1 in. in diameter, green with a purplish crown. In dry soil W. and S.

II. ASCLEPIAS L.

Perennial herbs. Flowers in simple (usually many-flowered) umbels. Calyx small, 5-parted, its lobes reflexed. Corolla deeply 5-parted, with reflexed lobes; crown of hoods and horns conspicuous (Fig. 27, *A*, *B*). Stamens with their filaments united into a tube around the pistil and anthers attached to the stigma (Fig. 27, *D*, *E*); anther cells 2, each cell containing an elongated, pear-shaped, tough mass of pollen, a mass from one anther always paired with one from the adjoining anther and each two together suspended from one of the 5 split glands on the angles of the stigma (Fig. 27, *D*, *E*). Ovaries 2; styles very short. Pods 2 or sometimes 1 and the other undeveloped. Seeds flat, each with a tuft of long, silky hairs. The flowers are pollinated by insects, which get their feet entangled in the clefts of the glands (Fig. 27, *g*) and then carry off the pollen masses.

1. **A. tuberosa** L. BUTTERFLY WEED, PLEURISY ROOT. Stems roughish-hairy, 1–2 ft. high. Juice not milky. Leaves abundant, linear to lanceolate-oblong. Flowers showy, usually bright orange, in terminal cymose umbels. Horns nearly erect and slender. Pods nearly erect, covered with fine down. In dry fields.

2. **A. decumbens** L. RECLINING BUTTERFLY WEED. Much resembling *A. tuberosa*, but the stems reclining with the ends erect. Leaves elliptic or oblong. Umbels racemed along the branches. In dry soil.

3. **A. purpurascens** L. PURPLE MILKWEED. Stem 1–3 ft. high, somewhat branched above. Leaves 4–6 in. long, elliptical or nearly so, the upper ones taper-pointed, slightly velvety beneath, short-petioled. Umbels terminal. Flowers $\frac{1}{2}$ in. long, dark purple; pedicels shorter than the peduncle; horn broadly scythe-shaped, with the point bent sharply inward. Dry soil.

4. A. syriaca L. COMMON MILKWEED. Stem stout, 3–4 ft. high, finely downy. Leaves 4–8 in. long, oblong or nearly so, downy beneath. Umbels terminal or nearly so. Flowers varying from purple or greenish-purple to whitish, numerous, with a strong, sweet but sickening odor; hoods with a tooth on each side of the stout horn. Common in rich soil.

5. A. phytolaccoides Pursh. POKE-LEAVED MILKWEED. Stem rather slender, 3–5 ft. high. Leaves 6–9 in. long, ovate or oval-lanceolate, taper-pointed, short-petioled. Umbels several, mostly lateral; pedicels slender and drooping. Lobes of the corolla greenish; hoods white, with 2 teeth; horns with an awl-shaped point extending far out of the hoods. Damp thickets N. and E.

6. A. variegata L. WHITE MILKWEED. Stem stout, leafless and smooth below, leafy and downy in lines above. Leaves opposite, the middle ones sometimes in fours, petioled, ovate to obovate, cuspidate, smooth on both sides, pale beneath, edges slightly crenate. Umbels 1–5, compact, downy, 1–2 in. long; pedicels erect, as long as the peduncles. Corolla white, often purple at the base; hoods roundish, spreading, a little longer than the thick, awl-pointed, incurved horn. Dry, open woods E. and S.*

7. A. quadrifolia L. FOUR-LEAVED MILKWEED. Stem slender, 1½–2 ft. or more high, usually leafless below. Leaves in 1 or 2 whorls of 4 each, near the middle of the stem, and a pair or two opposite, thin, slender-petioled, 2–4 in. long, ovate-lanceolate, taper-pointed. Umbels usually 2, sometimes 1, with slender pedicels. Corolla lobes very pale pink or whitish; hoods white; horn short, stout, and bent inward. Dry woods and fence rows.

III. HOYA R. Br.

Shrubby, more or less climbing, smooth, tropical plants. Leaves fleshy. Calyx 5-cleft; corolla 5-lobed, wheel-shaped, its divisions thick and with a waxy look; crown of 5 spreading segments; pollen masses fastened by the bases.

1. H. carnosa R. Br. WAX PLANT. Stems long and slender, rooting and trailing. Leaves oval or nearly so, thick, dark green. Flowers in close umbels, pink or whitish, the corolla lobes covered on the upper surface with minute projections. Cultivated from India as a house plant and in conservatories.

83. CONVOLVULACEÆ. MORNING-GLORY FAMILY

Usually twining herbs or shrubs, often with milky juice. Leaves alternate (wanting in *Cuscuta*), without stipules.

Flowers variously clustered, rarely solitary, often large and showy. Sepals 5. Corolla hypogynous, regular, tubular, bell-shaped or funnel-shaped; its limb more or less 5-lobed or angled. Stamens 5, inserted on the corolla tube. Ovary usually 2–4-celled; style slender, 2–4-cleft; ovules 1 or 2 in each cell. Capsule 1–4-celled, 2–4-valved, or bursting open across the base.

I. IMPOMŒA L.

Annuals or perennials; stems often twining. Flowers showy. Calyx not bracted at the base, of 5 sepals. Corolla bell-shaped or funnel-shaped, twisted in the bud. Stamens not projecting from the corolla. Style slender; stigma knobbed, 2-lobed. Fruit a 2–3-celled capsule. [*I. purpurea*, the common morning-glory, blossoms too late for school study. *I. Batatas*, the sweet potato, seldom flowers.]

B. Fl. species 1 (*Quamlocit*).

1. I. Quamlocit L. Cypress Vine. Stem slender, smooth, twining high. Leaves dark green, pinnately cut, the divisions linear, smooth. Peduncles slender, as long as the leaves, 1–5-flowered; pedicels thickened upward. Sepals ovate or oblong, mucronate. Corolla bright scarlet, or sometimes yellowish-white, salverform; the tube $1–1\frac{1}{2}$ in. long; the limb flat and spreading, $\frac{1}{2}–\frac{3}{4}$ in. wide. Capsule ovoid, twice the length of the sepals. Common in gardens.*

2. I. hederacea Jacq. Wild Morning-Glory. Stems hairy, twining. Leaves heart-shaped, 3-lobed. Peduncles 1–3-flowered. Calyx very hairy below. Corolla showy, bluish-purple or white. Pod usually 3-celled, with 2 seeds in each cell. A weed in fields and about dwellings. Introduced from tropical America.

3. I. pandurata G. F. W. Mey. Wild Potato Vine. Perennial, from a very large, tuberous root; stem trailing or twining, smooth or slightly downy, 5–10 ft. long. Leaves broadly heart-shaped, with the apex slender and obtuse, sometimes fiddle-shaped or 3-lobed; petioles slender. Peduncles longer than the petioles, 1–5-flowered. Sepals oblong, obtuse, smooth, mucronate, the 2 outer ones shorter. Corolla white with a purple throat, 2–3 in. wide, lobes pointed. Capsule globose, 2–3-seeded, the seeds woolly on the angles. On dry or damp sandy soil, along fences, railroad embankments, etc.; common S. and W.*

4. I. leptophylla Torrey. Bush Morning-Glory. Perennial. Stems smooth, much branched, erect, ascending or reclining, 2–4 ft.

long, from a huge root. Leaves 2–5 in. long, short-petioled, linear, acute. Peduncles short, 1–4-flowered. Sepals broadly ovate, obtuse. Corolla pink or purple, funnel-shaped, about 3 in. long. Pod ovoid, 2-celled. Plains W. and S.W.

II. CONVOLVULUS L.

Herbs or shrubs, with stems twining or nearly erect. Calyx not bracted, or inclosed in 2 large, leaf-like bracts. Corolla broadly funnelform or bell-shaped. Stamens not projecting from the corolla. Style 1; stigmas 2; ovary and pod 1–2-celled, 4-seeded.

1. **C. spithamæus** L. Downy, stem 6–12 in. high, erect or reclining. Leaves oblong, sometimes heart-shaped or eared at the base. Flowers white. Calyx inclosed by 2 large, oval, acutish bracts. Stigmas stout. In sandy soil.

2. **C. repens** L. Trailing Bindweed. Stems downy, 1–3 ft. long, trailing or twining. Leaves sometimes heart-shaped, often narrowly arrow-shaped, with the lobes at the base obtuse or rounded. Peduncles 1-flowered. Corolla white, or sometimes pink. Stigma ellipsoidal. Bracts beneath the calyx 2, ovate. In fields.

3. **C. sepium** L. Creepers, Rutland Beauty. Stem twining or sometimes extensively trailing. Leaves heart-arrow-shaped or somewhat halberd-shaped, the lobes at the base truncate. Flowers numerous and showy, white or tinged with rose color. Bracts at the base of the flower large, ovate, heart-shaped. Thickets and banks of streams, often cultivated.

4. **C. arvensis** L. Bindweed. A perennial, prostrate or climbing herb, with many stems, from a long, slender rootstock. Leaves very variable, more or less arrow-shaped, 1–3 in. long. Peduncles mostly 1-flowered; flowers white or pinkish, about $\frac{3}{4}$ in. long. Calyx not bracted. Stigmas linear. A weed in fields E.; adventive from Europe.

84. POLEMONIACEÆ. Phlox Family

Annual or perennial herbs, rarely shrubs. Leaves alternate or the lower opposite, without stipules. Flowers in terminal, forking cymes. Calyx hypogynous, 5-lobed. Corolla regular or nearly so, 5-parted. Stamens 5, inserted on the corolla tube, usually unequal. Ovary 3-celled; style simple; stigmas 3, linear; capsule 3-celled, the cells 1–many-seeded.

I. PHLOX L.

Perennial or rarely annual herbs; stems erect or diffuse. Leaves opposite, or the upper alternate, entire, without stipules. Flowers showy, white or purple, in terminal cymes or panicles. Calyx cylindrical or funnelform, 5-cleft, the lobes acute. Corolla salver-form, the tube long and slender, the limb 5-parted, the lobes spreading, entire or obcordate. Stamens included, unequal. Ovary 3-celled, style slender. Capsule ovoid, 3-celled, 1–few-seeded; seeds wingless or narrow-winged.*

1. **P. paniculata** L. GARDEN PHLOX. Perennial; stems in clumps, stout, erect, simple or branched above, 2–4 ft. high. Leaves ovate-lanceolate to oblong, taper-pointed at the apex, rounded or cordate at the base, thin, smooth; veins prominent beneath. Cymes numerous and compact, forming a pyramidal panicle; pedicels short. Calyx teeth long, bristle-pointed. Corolla purple to white; lobes round-obovate, shorter than the tube. Capsule longer than the calyx tube. In rich woods; often cultivated.*

2. **P. maculata** L. WILD SWEET WILLIAM. Stem erect, smooth or nearly so, rather slender, purple-spotted, 1–2 ft. high. Lower leaves lanceolate, the upper ones broader, taper-pointed, roundish or heart-shaped at the base. Panicle many-flowered, narrow, ellipsoidal. Calyx teeth lanceolate, hardly acute. Flowers purple, occasionally white. Damp woods and fields.

3. **P. glaberrima** L. SMOOTH PHLOX. Stems smooth, slender, erect, 1–3 ft. high. Leaves narrowly lanceolate or linear, 1½–4 in. long, smooth except the rough and sometimes recurved margins. Cymes few-flowered, grouped in loose corymbs. Calyx teeth very narrow and sharp-pointed. Corolla pink or whitish, lobes longer than the tube. Prairies and open woods.

4. **P. pilosa** L. DOWNY PHLOX. Perennial; stem erect, slender, simple or branched, 1–2 ft. high. Leaves linear-lanceolate to linear, distant, spreading, long, taper-pointed, sessile; stem and leaves downy. Cymes corymbose, loose. Flowers short-pediceled. Calyx glandular-viscid, the teeth shorter than the tube of the purple corolla, bristle-pointed. Corolla tube downy, lobes obovate. Capsule twice the length of the calyx tube. In dry, open woods.*

5. **P. divaricata** L. WILD BLUE PHLOX. Perennial; stems erect or ascending from a decumbent base, sticky-downy, 1 ft. high. Leaves distant, lanceolate to oblong, acute at the apex, rounded at the base, sessile, downy. Cymes corymbed, loosely flowered. Calyx teeth awl-shaped, longer than the tube. Corolla bluish-purple, ½–¾

in. long; lobes notched at the apex, as long as the tube. Capsule oval, shorter than the calyx teeth. In moist, open woods.*

6. P. Drummondii Hook. DRUMMOND'S PHLOX. Annual; stem erect or ascending, slender, weak, branching, glandular-downy, 6–12 in. high. Leaves mostly alternate, lanceolate to oblong, downy, the upper clasping by a heart-shaped base. Corymbs loose. Flowers rather long-pediceled. Calyx tube short, the teeth lanceolate, bristle-pointed, soon recurved. Corolla purple to crimson or white; orifice of the tube usually with a white or yellowish star-like ring; lobes rounded at the apex. Ovary 3-seeded; angles of the seeds winged. Introduced from Texas and common everywhere in gardens.*

7. P. subulata L. GROUND PINK, MOSS PINK, FLOWERING MOSS. Stems perennial, prostrate, 8–18 in. long, with many short, somewhat upright branches, 2–4 in. high. Leaves linear-awl-shaped, stiff, about ½ in. long, crowded, with clusters of smaller ones in their axils. Flower clusters 3–6-flowered. Corolla pink-purple, with a darker center, or sometimes white. Forms dense mats on rocky or sandy hillsides. S. and W. and often cultivated.

II. POLEMONIUM L.

Perennial herbs. Leaves alternate, pinnate. Flowers in corymbs. Calyx bell-shaped, 5-lobed. Corolla wheel-shaped, the limb with 5 obovate lobes. Stamens borne on the throat of the corolla, the filaments enlarged and hairy below. Capsule ovoid, 3-celled, many-seeded.

1. P. reptans L. JACOB'S LADDER, BLUE VALERIAN, BLUEBELL. Stems smooth, branched, and leaning over, 6–12 in. high. Leaflets usually 7 or 9, about an inch long. Corolla blue, about 3 times as long as the calyx. Capsule 3-seeded, borne on a short stalk in the persistent calyx. Damp, open woods, sometimes cultivated.

85. HYDROPHYLLACEÆ. WATERLEAF FAMILY

Herbs, usually hairy. Leaves commonly alternate and alternate-lobed. Flowers with their parts in fives, in appearance not unlike those of the following family, in one-sided cymes, which are coiled up at first. Calyx free from the ovary, usually with appendages at the notches. Corolla often with scales or nectar-bearing folds inside. Stamens borne by the corolla tube. Style 2-cleft, or styles 2. Ovary entire and usually 1-celled. Fruit a capsule, 2-valved, 4–many-seeded.

I. HYDROPHYLLUM L.

Coarse perennials. Leaves large, petioled. Flowers white or pale blue, inconspicuous. Calyx 5-parted, sometimes appendaged at the notches. Corolla bell-shaped, 5-cleft, with 5 double, nectar-bearing folds inside. Stamens projecting, the filaments bearded. Style projecting; ovary covered with bristly hairs, the placentæ very broad and fleshy, inclosing the ovules. Capsule globular, 1–4-seeded.

1. H. macrophyllum Nutt. A coarse, rough-hairy plant, about 1 ft. high, from scaly-toothed rootstocks. Leaves oblong, pinnate and pinnately cut, the divisions mucronate, obtuse, coarsely toothed. Flower cluster dense, globular, long-peduncled. Flowers about ½ in. long. Calyx little or not at all appendaged, its lobes broad at the base, but with slender, tapering points. Corolla white. Rich, rocky woods W. and S.

2. H. virginianum L. Nearly smooth, 1–2 ft. high, stem often forking at the base. Leaves of the stem mostly near the top, pinnately cut into 5–7 divisions; lobes oval-lanceolate, deeply serrate, the lowest ones distinct; petioles of the basal and lower leaves 4–8 in. long. Flower clusters on peduncles longer than the petioles of the upper leaves, from the axils of which or opposite which they arise. Flowers about ¼ in. long. Calyx not appendaged, its lobes narrowly linear, bristly-margined. Corolla whitish, with purplish veins. Moist woods.

3. H. appendiculatum Michx. Hairy, 1–1½ ft. high. Stem leaves palmately 5-lobed, the lobes acute, toothed, lowest ones pinnately divided. Flower cluster rather loose. Calyx appendaged at the notches. Corolla blue. Stamens projecting from the corolla little or not at all. Moist woods.

II. ELLISIA L. (MACROCALYX)

Delicate, branching annuals. Leaves pinnately lobed or divided. Flowers small, whitish. Calyx without appendages, 5-parted, enlarged and leafy in fruit. Corolla bell-shaped or cylindrical, little if any longer than the calyx, 5-lobed, with 5 minute appendages within the tube. Placentæ, fruit, and seeds nearly as in *Hydrophyllum.*

1. E. Nyctelea L. Plant somewhat roughish-hairy, 6–12 in. high. Leaves pinnately parted or divided. Peduncles 1-flowered, opposite the leaves. Corolla whitish. Pod globose, finally pendulous. In damp, shady places.

III. PHACELIA Juss.

Herbs, mostly annual. Leaves alternate, sometimes simple, but in most species lobed or divided. Flowers in one-sided clusters, often showy. Calyx 5-parted, without appendages. Corolla with 5 spreading lobes. Ovary 1-celled, with narrow placentæ.

1. **P. bipinnatifida** Michx. A hairy biennial. Stem upright, 1–2 ft. high. Leaves on long petioles, pinnately divided or deeply cut into 3–7 toothed or cut segments. Racemes long, loose, many-flowered. Flowers blue or violet, the spreading or recurved pedicels about as long as the calyx. Calyx segments linear. Corolla broadly bell-shaped, its appendages in pairs between the stamens. Rich soil in thickets and along streams.

2. **P. tanacetifolia** Benth. A tall, hairy annual. Leaves pinnately cut. Spikes long, densely flowered. Flowers showy, blue. Stamens projecting. Capsule 4-seeded. Cultivated from California.

3. **P. Whitlavia** Gray. WHITLAVIA. A rather coarse, sticky annual. Leaves broad, ovate, coarsely toothed, petioled. Flower clusters a loose raceme. Flowers showy, about 1 in. long, blue or sometimes white. Corolla bell-shaped. Stamens and style projecting. Capsule many-seeded. Cultivated from California.

4. **P. linearis** Holz. EUTOCA. A much-branched, somewhat rough or rough-hairy plant, 3–12 in. high. Leaves linear or lanceolate, entire or nearly so. Flowers showy, violet or white, loosely panicled. Capsule many-seeded. Cultivated from California.

86. BORAGINACEÆ. Borage Family

Mostly herbs, with stems and foliage roughened with stiff hairs. Leaves alternate and entire, not aromatic. Flowers generally in a coiled inflorescence. Calyx 5-parted. Corolla hypogynous, generally 5-lobed and regular. Stamens 5, inserted on the corolla tube. Style 1; ovary commonly 4-lobed, ripening into 4 1-seeded nutlets.

I. HELIOTROPIUM L.

Herbs or low shrubs. Leaves petioled. Flowers white, blue, or lilac, in one-sided, curved spikes. Calyx 5-parted. Corolla salver-shaped, the throat open. Anthers almost sessile. Style short; stigma conical or knobbed. Fruit separating into 2 or 4 nutlets.

1. **H. peruvianum** L. COMMON HELIOTROPE. Somewhat shrubby, much branched. Leaves lance-ovate or somewhat oblong, veined and much wrinkled, short-petioled. Flowers numerous, in a cluster of terminal spikes, bluish-purple or lavender, very sweet-scented, the odor not unlike that of vanilla. Cultivated from Peru.

II. CYNOGLOSSUM L.

Coarse, rough-hairy or silky biennials. Flowers small, bluish-purple or white, in forked and usually bractless cymes. Calyx 5-parted. Corolla funnel-shaped, the mouth closed by prominent scales, its lobes obtuse. Stamens not projecting. Styles stiff, persistent. Nutlets 4, covered with hooked or barbed bristles, attached to a thickened, conical receptacle.

1. **C. officinale** L. HOUND'S-TONGUE, SHEEP LICE, DOG BUR, STICK-TIGHTS. Stem 1–2 ft. high, soft-downy, panicled above. Basal leaves 8–10 in. long, long-petioled, oblong or oblong-lanceolate; stem leaves sessile, linear-oblong or lanceolate, rounded or heart-shaped at the base. Corolla $\frac{1}{2}$ in. in diameter, reddish-purple. Nutlets $\frac{1}{4}$ in. long, with a thickened border. Whole plant with a strong smell like that of mice. A troublesome weed; along roadsides and in pastures; naturalized from Europe.

2. **C. virginianum** L. WILD COMFREY. Perennial. Stem stout, simple, erect, leafless above, 2–3 ft. high. Leaves oval or oblong, the upper clasping by a heart-shaped base. Racemes bractless; flowers pale blue, on short pedicels, which are recurved in fruit. Nutlets not margined, separating and falling away at maturity. On dry soil.

III. LAPPULA Moench.

Annual or biennial herbs, grayish, with rough hairs. Flowers small, blue or whitish, racemed or spiked. Corolla salver-shaped, its throat closed with 5 concave scales. Nutlets more or less covered with prickles, which are barbed at the tip, attached by their sides to the base of the style.

1. **L. virginiana** Greene. BEGGAR'S LICE. A coarse biennial, 2–4 ft. high, the stem much branched above. Basal leaves roundish-ovate or heart-shaped, on slender petioles; stem leaves 3–4 in. long, pointed at both ends. Racemes 1–3 in. long, terminating the slender, spreading branches; flowers small, bluish-white. Fruit forming a troublesome bur. Fence rows and thickets.

IV. MYOSOTIS L.

Low, annual, biennial, or perennial herbs; stems branching, erect, or diffuse. Leaves alternate, entire. Flowers small, blue, pink, or white, in elongated, bractless racemes. Calyx 5-cleft, the lobes erect or spreading in fruit. Corolla salverform, 5-lobed, the tube as long as the calyx, the throat with 5 small appendages. Stamens 5, inserted in the tube of the corolla, included. Ovary 4-parted; style slender. Nutlets smooth or downy, elliptical, compressed.*

1. **M. scorpioides** L. FORGET-ME-NOT. Perennial, from slender rootstocks; stems slender, downy, rooting at the nodes, 6–15 in. long. Leaves oblong to oblong-lanceolate, obtuse, narrowed to the sessile base, appressed-downy. Racemes many-flowered; pedicels becoming elongated in fruit. Lobes of the calyx shorter than the tube, spreading in fruit. Corolla blue, with a yellow eye. Nutlets angled, smooth. In gardens and often naturalized from Europe.*

2. **M. laxa** Lehm. SMALL FORGET-ME-NOT. Annual or perennial; whole plant downy; stem slender, weak, decumbent and rooting at the base, 1–2 ft. long. Lower leaves spatulate, the upper lanceolate. Racemes loosely flowered, becoming elongated in fruit; pedicels spreading. Calyx rough-hairy, the lobes as long as the tube. Corolla pale blue, with a yellow eye. Nutlets convex on all sides. On low ground and in brooks and ponds.*

V. MERTENSIA Roth.

Perennial herbs. Leaves generally pale, smooth, and entire. Calyx short, deeply 5-cleft or 5-parted. Corolla somewhat trumpet-shaped or funnel-shaped, often with 5 small folds or ridges in the throat, between the points of insertion of the stamens. Style long and slender. Nutlets smooth, or at length becoming wrinkled.

1. **M. virginica** Link. LUNGWORT, BLUEBELLS. Smooth, nearly erect, 1–1½ ft. high. Basal leaves large, obovate or nearly so, and petioled; stem leaves smaller, sessile. Flowers clustered. Corolla nearly trumpet-shaped, varying with age from lilac to blue (or occasionally white). Stamens with slender filaments projecting beyond the corolla tube. Damp, open woods, and banks of streams; sometimes cultivated.

VI. LITHOSPERMUM L.

Herbs, with stout, usually reddish roots. Flowers appearing axillary and solitary or else in leafy-bracted spikes. Corolla funnel-shaped or salver-shaped, with or without folds or appendages at the mouth of the tube; the limb 5-cleft, its divisions rounded. Stamens included in the corolla tube, the anthers nearly sessile. Nutlets either smooth or wrinkled, generally very hard and bony.

1. **L. arvense** L. CORN GROMWELL. A rough weed, about 1 ft. high. Leaves narrowly lanceolate. Flowers inconspicuous, whitish, in the upper leaf axils. Corolla hardly extending beyond the calyx, without appendages in the throat. Nutlets rough or wrinkled and dull. Sandy banks and roadsides; naturalized from Europe.

2. **L. Gmelini** Hitchc. HAIRY PUCCOON. Rough-hairy, perennial, 1–2 ft. high. Corolla deep orange-yellow, with appendages in the throat and clad with wool within at the bottom; flowers handsome, peduncled, in a crowded cluster. Dry, open pine woods, in sandy soil.

3. **L. canescens** Lehm. PUCCOON, INDIAN PAINT. Perennial; clothed with soft hairs, 8–12 in. high. Flowers axillary and sessile. Corolla appendaged, not woolly within, showy, orange-yellow. Banks and open woods.

4. **L. angustifolium** Michx. NARROW-LEAVED PUCCOON. Perennial; rough, 6–18 in. high, from a deep root. Leaves linear, sessile, acute or nearly so. Flowers pediceled in terminal leafy racemes of two kinds, the earlier showy, bright yellow, with a corolla tube an inch or more long; the latter much smaller, pale yellow, cleistogamous, fruiting abundantly. Pedicels of the cleistogamous flowers at length recurved. Nutlets ovoid, white, very smooth, slightly pitted. In dry soil W.

VII. ONOSMODIUM Michx.

Mostly rough-hairy perennial herbs. Leaves sessile, entire, with prominent veins. Flowers rather small, white, greenish or yellowish, in leafy one-sided spikes or racemes. Calyx 5-parted into linear divisions. Corolla tubular or tubular-funnelform, with 5 acute erect lobes. Stamens 5, perigynous, not projecting from the corolla tube. Style thread-like, decidedly projecting. Nutlets usually only 1 or 2, white, smooth and shining.

1. **O. virginianum** A.DC. Stems rather slender, 1–3 ft. high, covered with rough, stiff bristles. Leaves oblong or oblong-lanceolate,

the lower ones narrowed at the base. Corolla narrow, its lobes lance-awl-shaped, slightly bearded outside with long bristles. In dry thickets or on hillsides.

2. O. hispidissimum Mackenzie. Stem stout, upright, 1–4 ft. high, shaggy with long bristly hairs. Leaves from lanceolate to oblong, acute, 2–4½ in. long. Corolla rather broad, its lobes ovate-triangular or triangular-lanceolate, thickly hairy outside. Nutlets with a very short neck at the base. Rich soil along river banks and bottom lands.

VIII. ECHIUM L.

Herbs or sometimes shrubs, usually stout, coarse, and hairy. Leaves entire. Flowers white, reddish-purple or blue, in spiked or panicled racemes. Calyx 5-parted. Corolla tube cylindrical or funnel-shaped; the throat dilated; the limb with 5 unequal lobes. Filaments unequal, attached to the corolla below, projecting from the corolla. Style thread-like; stigma 2-lobed. Nutlets 4, ovoid or top-shaped, wrinkled.

1. E. vulgare L. Blue Thistle, Blue Weed, Blue Devils. Stems 1–3 ft. high, more or less erect, leafy, covered with stinging hairs. Root leaves lanceolate or oblong, petioled, 4–8 in. long; stem leaves sessile, acute, rounded at the base. Flowers showy, reddish-purple in the bud, changing to bright blue. A very troublesome weed, especially in fallow fields. Naturalized from Europe.

87. VERBENACEÆ. Verbena Family

Herbs, shrubs, or trees. Leaves opposite or whorled, without stipules. Flowers zygomorphic, in bracted cymes. Calyx hypogynous, cleft or toothed. Corolla hypogynous, tubular, usually more or less 2-lipped. Stamens usually 4 (2 long and 2 short), inserted on the corolla tube. Ovary usually 2–4-celled (in *Phryma* 1-celled), with the style springing from its summit.

I. VERBENA L.

Annual or perennial herbs. Leaves simple, opposite, serrate or pinnately lobed. Flowers in terminal spikes which become much elongated in fruit. Calyx tubular, 5-ribbed, 5-toothed. Corolla salverform or funnelform, the tube often curved, bearded in the throat, limb spreading, 5-lobed, often

somewhat 2-lipped. Stamens 4 (2 long and 2 short), rarely only 2, included. Ovary 2–4-celled, 2–4-ovuled; style slender, 2-lobed. Fruit 2–4 smooth or roughened, 1-seeded nutlets. [Several of the commonest species are tall, coarse herbs, which blossom too late for school study.]*

1. V. officinalis L. EUROPEAN VERVAIN. Annual; stem erect, slender, nearly or quite smooth, branching, 1–3 ft. high. Leaves ovate to obovate in outline, pinnately lobed or divided, narrowed and entire toward the base, downy beneath; petioles margined. Spikes several, very slender; flowers small, purple; bracts shorter than the calyx. In fields and waste places. Naturalized from Europe.*

2. V. angustifolia Michx. NARROW-LEAVED VERVAIN. Perennial, rough-hairy; stem simple, or branched below, from a creeping base, 1–2 ft. high. Leaves lanceolate to spatulate, obtuse and toothed at the apex, tapering to a sessile base. Spike peduncled, slender, close-flowered; bracts about the length of the calyx. Corolla purple, tube slightly curved, $\frac{1}{4}$ in. long. In dry, open woods.*

3. V. bracteosa Michx. Perennial; widely spreading or decumbent, hairy; stems 6–15 in. long, 4-sided, branching from the base. Leaves wedge-lanceolate, 3-cleft or pinnately cut, short-petioled. Spikes sessile, stout, with large bracts, the lower ones pinnately cut and longer than the flowers. Flowers small, purple. On prairies and waste ground.

4. V. bipinnatifida Nutt. Perennial; plant rough-hairy, producing suckers, erect, 6–18 in. high. Leaves with petioles, or the upper ones sessile, once or twice pinnately parted into oblong or linear divisions. Spikes stout, dense and solitary at the ends of the branches; bracts usually longer than the calyx. Corolla bluish-purple or lilac, less than $\frac{1}{2}$ in. in diameter. Dry plains and prairies W. and S.

5. V. canadensis Britton. WILD VERBENA. A slender-stemmed, somewhat reclining annual, 1 ft. or less in height. Leaves ovate or nearly so, wedge-shaped at the base, lobed and toothed or 3-cleft. Flowers showy, reddish-purple or lilac (seldom white), in a peduncled spike. Calyx teeth as long as or longer than the bracts. Corolla very slightly bearded in the throat. In dry prairie soil and open woods; also cultivated. [Other somewhat similar cultivated species are from Brazil.]

II. CALLICARPA L.

Shrubs. Leaves simple, petioled, opposite or whorled, glandular-dotted. Flowers in axillary cymes. Calyx 4-toothed or entire. Corolla funnelform, 4-cleft, actinomorphic. Stamens 4, equal, projecting. Ovary 4-ovuled; style slender; stigma knobbed. Fruit a 1–4-seeded berry.*

1. C. americana L. French Mulberry, Mexican Mulberry. Shrubs, with star-shaped glandular or scurfy down, widely branched, 3–8 ft. high. Leaves ovate to oblong, acute at each end, crenate-serrate, rough above, downy beneath, glandular-dotted; petioles slender. Cymes many-flowered, the peduncle as long as the petiole; pedicels short. Calyx cup-shaped, the teeth short. Corolla double the length of the calyx, blue. Fruit violet-purple, very conspicuous in autumn. Common in fields and thickets S.*

88. LABIATÆ. Mint Family

Mostly herbs, with square stems and opposite, more or less aromatic, leaves, without stipules. Flowers generally in cyme-like axillary clusters, which are often grouped into terminal spikes or racemes. Calyx tubular, usually 2-lipped, persistent. Corolla usually 2-lipped. Stamens 4 (2 long and 2 short) or only 2. Ovary free, with 4 deep lobes, which surround the base of the style. Fruit consisting of 4 nutlets, ripening inside the base of the calyx.

A

Stamens 4.

(*a*) Calyx 2-lipped.

Lips entire. Scutellaria, I

Lips toothed and cleft. Plants not aromatic. Prunella, IV

Lips toothed and cleft. Plants aromatic. Leaves extremely small. Thymus, IX

(*b*) Calyx not 2-lipped, or not much so.

Calyx tubular, 5–10-toothed. Stamens not projecting from tube of corolla. Marrubium, II

Calyx tubular, with 5 equal teeth. Stamens under upper lip of corolla. Nepeta, III

Calyx tubular, bell-shaped, with 5 awl-shaped teeth. Stamens not turned down after maturing. Lamium, V

Calyx top-shaped, with spreading spiny teeth. Leonurus, VI

Calyx as in V. Stamens turned down after maturing. Stachys, VII

B

Stamens 2. Salvia, VIII

I. SCUTELLARIA L.

Mostly slender herbs, not aromatic. Flowers solitary or in pairs, axillary or in terminal spikes or racemes. Calyx bell-shaped, 2-lipped, the upper part swollen into a helmet-shaped pouch; mouth of the calyx closed after flowering. Corolla tube long, naked inside. Stamens 4, the anthers meeting in pairs, hairy-fringed. Style with a very short upper lobe. [The species here described are not the commonest ones, but most of the others grow in damp soil and bloom later.]

1. **S. serrata** Andr. SKULLCAP. Stem not much branched, 1–3 ft. high. Stem leaves serrate, taper-pointed at both ends, ovate or nearly so. Racemes single, loose. Calyx rather hairy. Corolla 1 in. long, the lips of equal length. Woods.

2. **S. pilosa** Michx. HAIRY SKULLCAP. Stem more or less hairy, not much if at all branched, 1–3 ft. high. Leaves a few distant pairs, diamond-ovate, oblong-ovate, or roundish-ovate, scalloped, obtuse, the lower heart-shaped or nearly truncate at the base, with long petioles. Racemes short, few-flowered. Corolla $\frac{1}{2}$ in. long; tube whitish, lips blue, the lower one rather shorter. Open woodlands and dry soil.

3. **S. integrifolia** L. LARGE-FLOWERED SKULLCAP. Stem covered with fine, grayish down, usually unbranched, 1–2 ft. high. Leaves lance-oblong or nearly linear, mostly entire, obtuse, with very short petioles. Corolla 1 in. long, tube pale, lips large and spreading, blue. Dry ground.

4. **S. parvula** Michx. SMALL SKULLCAP. Perennial with necklace-like tuber-bearing rootstocks. Stems slender, minutely downy, 3–12 in. long, erect or spreading. Leaves varying from ovate to lanceolate, or the lower nearly round. Flowers solitary in the axils of the upper leaves. Corolla $\frac{1}{6}$–$\frac{1}{3}$ in. long, violet, downy. In moist, sandy soil.

II. MARRUBIUM L.

Perennial, downy, or woolly herbs. Whorls of flowers axillary; flowers small; bracts leaf-like. Calyx tubular, 5–10-toothed; teeth somewhat spiny. Corolla short; upper lip erect, lower spreading, 3-cleft, the middle lobe broadest. Stamens 4, not projecting. Lobes of the stigma short and blunt.

1. **M. vulgare** L. HOREHOUND. Stems somewhat reclining, stout, branching, leafy, 1–1$\frac{1}{2}$ ft. high. Leaves broadly ovate, heart-shaped or wedge-shaped at the base, scalloped, leathery and wrinkled. Whorls

of flowers dense. Calyx teeth hooked at the tip. Corolla $\frac{1}{2}$ in. long, white. Cultivated from Europe as an herb (used in preparation of horehound candy) and somewhat naturalized.

III. NEPETA L.

Erect or prostrate herbs. Whorls of flowers axillary or terminal; flowers blue or white. Calyx tubular, 15-ribbed, 5-toothed. Corolla tube slender below, dilated at the throat, naked; upper lip notched or 2-cleft; lower lip 3-cleft, middle lobe large. Stamens 4, ascending under the upper lip, the upper pair longer. Lobes of the stigma awl-shaped.

B. Fl. species 2 (*Glecoma*).

1. N. Cataria L. CATNIP. Stem grayish, downy, 2–3 ft. high, branched, very leafy. Leaves large, ovate-heart-shaped, deeply scalloped, serrate, white and downy beneath. Corolla about $\frac{1}{2}$ in. long, whitish with purple dots. Naturalized from Europe; a common weed about dooryards.

2. N. hederacea Trevisan. GROUND IVY, GILL-OVER-THE-GROUND, CREEPING CHARLEY, CROW VICTUALS, ROBIN RUNAWAY. Creeping. Leaves roundish, kidney-shaped, and crenate. Corolla bluish-purple, three times as long as the calyx. Common in damp places about houses and gardens. Naturalized from Europe.

IV. PRUNELLA L.

Perennials, with stems simple or nearly so, and sessile, 3-flowered flower clusters in the axils of kidney-shaped bracts, the whole forming a spike or head. Calyx tubular-bell-shaped, somewhat 10-ribbed; upper lip broad, 3-toothed, the teeth short; lower lip with 2 longer teeth. Upper lip of the corolla upright, arched, and entire; the lower spreading, reflexed, fringed, and 3-cleft. Stamens 4, reaching up under the upper lip, with the tips of the filaments 2-toothed; only one tooth anther-bearing.

1. P. vulgaris L. SELF-HEAL, HEALALL, CARPENTER WEED. Leaves with petioles, ovate-oblong, either entire or toothed, often somewhat hairy. Corolla usually blue or bluish, somewhat longer than the brown-purple calyx. Open woods and fields everywhere.

V. LAMIUM L.

Annual or perennial hairy herbs. Calyx tubular-bell-shaped, 5-veined, with 5 awl-pointed teeth of nearly equal length.

Corolla with dilated throat, upper lip arched, middle lobe of the lower lip notched, the lateral lobes small, close to the throat of the corolla. Stamens 4, rising beneath the upper lip.

1. L. amplexicaule L. HENBIT, DEAD NETTLE. An annual or biennial weed. Leaves roundish, deeply scalloped, the lower ones petioled, the upper sessile and clasping. Corolla sometimes $\frac{3}{4}$ in. long, downy, rose-colored or purplish. Not uncommon about gardens and dooryards. Naturalized from Europe.

2. L. purpureum L. Stem 6–18 in. high, silky-hairy or nearly smooth, reclining below, branched from the base. Leaves long-petioled, obtuse, heart-shaped, scalloped. Whorls of flowers mostly terminal, crowded. Corolla $\frac{1}{2}$–$\frac{3}{4}$ in. long, purple (rarely white). Naturalized from Europe.

VI. LEONURUS L.

Erect herbs. Leaves lobed. Whorls of flowers axillary, densely flowered, scattered; bractlets awl-shaped; flowers small, pink or white. Calyx 5-nerved, top-shaped, with 5 rather spiny, spreading teeth. Corolla with upper lip erect and entire, lower 3-cleft. Stamens 4; anthers joined in pairs. Nutlets with 3 projecting angles, their sides channeled.

1. L. cardiaca L. MOTHERWORT. Stem 2–4 ft. high, prominently angled, stiff, stout, upright, very leafy. Leaves palmately lobed or cleft; basal ones long-petioled; lower stem leaves many-cleft, the upper ones 3-cleft, prominently nerved, the divisions acute. Corolla $\frac{1}{2}$ in. long, pale rose color, the upper lip and outside of the tube densely soft-bearded. Common about dooryards and fence rows. Naturalized from Europe.

VII. STACHYS L.

Herbs, rarely shrubs. Leaves scalloped or serrate. Whorls of flowers 2 or more flowered, usually in terminal racemes. Calyx nearly bell-shaped, 5-toothed. Corolla tube cylindrical, usually with a ring of hairs inside, not dilated at the throat; upper lip erect or spreading; lower spreading, 3-lobed, the middle lobe largest. Stamens 4, the 2 lower longest.

1. S. palustris L. Perennial; stem erect, 4-angled, 2–3 ft. high, hairy, especially on the angles, with projecting or reflexed hairs, leafy. Stem leaves short-petioled or sessile, ovate-lanceolate or oblong-lanceolate, scalloped-serrate, coarsely or finely downy, roundish

at the base, rather obtuse at the tip. Calyx bristly, the lance-awl-shaped teeth rather spiny. Upper lip of the corolla downy. In wet soil, especially N.

2. S. tenuifolia Willd., var. **aspera**. Taller than No. 1; angles of the stem covered with stiff reflexed bristles, but the sides often smooth. Leaves serrate, nearly all with distinct petioles. Calyx usually smooth. Corolla smooth throughout. Damp thickets and along streams.

VIII. SALVIA L.

Annual, biennial, or perennial herbs, or sometimes shrubby. Flowers in spikes, racemes, or panicles, usually showy. Calyx tubular or bell-shaped, not bearded in the throat, 2-lipped, the upper lip entire or 3-toothed, the lower 2-cleft. Corolla 2-lipped; the upper lip entire or notched, the lower spreading, 3-lobed, with the middle lobe longer. Stamens 2, short; anthers 2-celled, the upper cell fertile, the lower imperfect. Style 2-cleft. Nutlets smooth.*

1. S. lyrata L. Lyre-leaved Salvia. Biennial or perennial; stem erect, sparingly branched above, rough-hairy, 1–2 ft. high. Leaves mostly basal, spreading, lyrate-pinnatifid, usually purple; stem leaves small, sessile or short-petioled. Racemes many-flowered, whorls about 6-flowered. Calyx teeth short on the upper lip, long and awl-shaped on the lower. Corolla blue or purple; the tube about 1 in. long, dilated upward. On dry soil.*

2. S. officinalis L. Garden Sage. Stem shrubby, slender, much branched below, 1 ft. high. Leaves grayish-green, lance-oblong, crenate, wrinkled. Flowers in terminal spikes, whorls several-flowered. Corolla blue, upper lip strongly arched, about equaling the lower. A common garden herb. Cultivated from Europe.*

IX. THYMUS L.

Small, much-branched shrubs, very aromatic. Leaves small, entire, margins often rolled under. Whorls of flowers few-flowered, in loose or close spikes; bracts very small; flowers usually purple. Calyx ovoid, 2-lipped; upper lip 3-toothed; lower 2-cleft, woolly in the throat. Corolla slightly 2-lipped. Stamens 4, usually projecting from the flower, straight; lower pair longer.

1. T. Serpyllum L. Creeping Thyme. Smooth or hairy, stem prostrate, the flowering branches somewhat ascending. Leaves $\frac{1}{8}$–$\frac{1}{4}$

in. long, flat, ovate or obovate-lanceolate, obtuse. Flowers crowded in spikes at the end of the branches. Corolla rose-purple, $\frac{1}{4}$–$\frac{3}{4}$ in. long. Naturalized from Europe.

2. T. vulgaris L. GARDEN THYME. More erect than No. 1. Leaves somewhat curled under at the edges. Flower clusters shorter and not all terminal. Corolla pale purple. Cultivated from Europe as an herb.

89. SOLANACEÆ. NIGHTSHADE FAMILY

Mostly tropical herbs or shrubs (rarely trees). Leaves usually alternate, without stipules. Flowers actinomorphic, borne on bractless pedicels at or above the leaf axils, or in cymes. Calyx hypogynous, 5-cleft, usually persistent. Corolla hypogynous, wheel-shaped, bell-shaped, or salver-shaped, 5-lobed. Stamens 5, short, inserted on the corolla tube. Ovary 2-celled or imperfectly 4-celled; style simple; stigma simple or lobed. Fruit a many-seeded capsule or berry.

I. SOLANUM L.

Herbs or shrubs; stems often prickly, sometimes climbing. Leaves alternate, often nearly or quite opposite. Flowers clustered, the peduncles often opposite or above the axils. Calyx spreading, 5-toothed or 5-cleft, persistent. Corolla wheel-shaped, 5-lobed. Stamens 5, projecting, the filaments very short, the anthers long and meeting about the style. Ovary 2-celled; style slender. Fruit a many-seeded, juicy berry.*

1. S. Dulcamara L. BITTERSWEET. Perennial; stems rather shrubby, long, and climbing. Leaves heart-shaped, or some of them with irregular lobes, or ear-like leaflets at the base. Flowers blue or purple, somewhat cymose. Berries showy, of many shades of orange and red in the same cluster, according to their maturity. Naturalized from Europe.

2. S. nigrum L. NIGHTSHADE. Annual; stem smooth, or downy with simple hairs, erect, diffusely branched; branches wing-angled, 1–3 ft. high. Leaves ovate, irregularly toothed or entire, somewhat inequilateral, petioled. Flowers in lateral, peduncled umbels, small, white, drooping. Calyx lobes obtuse; corolla $\frac{1}{3}$–$\frac{1}{2}$ in. wide; filaments downy; berries globose, smooth, black when ripe. Common in cultivated fields and waste places.*

3. S. carolinense L. HORSE NETTLE. Perennial; stem erect, branched, downy with star-shaped hairs, armed with straight yellow prickles, 1–3 ft. high. Leaves ovate-oblong, deeply toothed or lobed, acute at the apex, abruptly contracted to the short petiole, prickly on the veins. Racemes lateral, few-flowered; pedicels recurved in fruit. Calyx lobes taper-pointed. Corolla deeply angular-lobed, blue or white; berry globose, smooth, yellow. A common weed.*

4. S. rostratum Dunal. SAND BUR, BUFFALO BUR. Annual; the whole plant beset with yellow prickles; stem erect, diffusely branched, 1–2 ft. high. Leaves broadly oval or ovate in outline, deeply pinnately lobed or parted, petioled, downy with star-shaped hairs. Racemes few-flowered; pedicels erect in fruit. Calyx very prickly, becoming enlarged and inclosing the fruit. Corolla bright yellow, 5-angled, about 1 in. broad. From the West, becoming a troublesome weed in some places.*

5. S. tuberosum L. IRISH POTATO. Annual; stem diffusely branched, downy, underground branches numerous and tuber-bearing. Leaves irregularly pinnatifid and divided. Flowers in cymose clusters, white or purple, with prominent yellow anthers; pedicels jointed. Corolla 5-angled, $\frac{3}{4}$–1 in. broad. Fruit a globose, greenish-yellow, many-seeded berry, about $\frac{1}{2}$ in. in diameter. Cultivated from Chile.*

II. LYCOPERSICUM Hill.

Annual; stem diffusely branched. Leaves pinnately divided. Flowers in raceme-like clusters on peduncles opposite the leaves. Calyx 5–many-parted, persistent. Corolla wheel-shaped, 5–6-parted. Stamens 5–6, inserted in the short tube of the corolla; filaments short, anthers elongated. Ovary 2–several-celled; style and stigma simple. Fruit a many-seeded berry.*

1. L. esculentum Mill. TOMATO. Stem diffusely branched, at length leaning over, furrowed and angled below, sticky-hairy, 3–5 ft. long. Leaves irregularly lobed and pinnatifid, petioled. Calyx lobes linear, about as long as the yellow corolla. Fruit (in the wild state) globose or ovoid, red or yellow, $\frac{1}{4}$–$\frac{1}{2}$ in. in diameter, but greatly enlarged in cultivation. Common in cultivation from tropical America.*

III. LYCIUM L.

Shrubs or woody vines, often spiny. Leaves entire, alternate, often fascicled. Flowers solitary or clustered, terminal

or axillary. Calyx persistent, 4–5-lobed or toothed, not enlarged in fruit. Corolla funnelform or bell-shaped, the limb 4–5-lobed, the lobes obtuse. Stamens 4–5, projecting. Ovary 2-celled; style single; stigma obtuse. Fruit a many-seeded berry.*

1. L. halimifolium Mill. MATRIMONY VINE. Stem slender, branching, twining or trailing, 6–15 ft. long; branches angled, spiny. Leaves elliptical, smooth, entire, sessile or short-petioled. Flowers solitary or few in the axils; peduncles long and slender. Corolla spreading, greenish-purple, $\frac{1}{3}$–$\frac{1}{2}$ in. wide. Berry oval, orange-red. Introduced from Africa, and often planted for covering trellises.*

IV. DATURA L.

Annual or perennial, strong-scented herbs; stems tall and branching. Leaves petioled, entire or lobed. Flowers large, solitary in the forks of the branches. Calyx tubular, 5-toothed or lobed, the upper part deciduous and the lower persistent. Corolla funnelform, 5-angled. Stamens 5, inserted in the corolla tube. Ovary 2-celled or imperfectly 4-celled; style filiform; stigma 2-lobed. Fruit a spiny, 4-valved, many-seeded capsule.*

1. D. Stramonium L. JIMSON WEED. Annual; stem smooth, green, stout, forking above, 1–4 ft. high. Leaves ovate to oblong-ovate, acute at the apex, narrowed at the base, sinuate-toothed, petioled. Calyx 5-angled. Corolla white, about 4 in. long. Capsule ovoid, erect, 2 in. long. A common weed; poisonous. Naturalized from Asia (?).*

2. D. Tatula L. Taller, with a purple stem; flowers rather later than No. 1. Corolla violet-tinged. Naturalized from tropical America.

V. PETUNIA Juss.

Herbs; leaves alternate and entire. Divisions of the calyx oblong-spatulate. Corolla showy, spreading, funnel-shaped, not perfectly actinomorphic. Stamens 5, somewhat unequal in length, inserted in the middle of the corolla tube and not projecting beyond it. Capsule 2-celled, containing many very small seeds.

1. P. violacea Lindl. COMMON PETUNIA. Stems rather weak and reclining. Leaves covered with clammy down. Corolla varying from pale pink to bright purplish-red, often variegated, with a broad, inflated tube, which is hardly twice as long as the calyx. Cultivated annual from South America.

2. **P. nyctaginiflora** Juss. WHITE PETUNIA. Leaves somewhat petioled. Tube of corolla long and slender. Flowers white. Cultivated from South America. This and the preceding species much mixed by hybridization.

90. SCROPHULARIACEÆ. FIGWORT FAMILY

Mostly herbs, with flowers not actinomorphic. Calyx free from the ovary and persistent. Corolla often 2-lipped. Stamens usually 2 long and 2 short, or only 2 in all, inserted on the corolla tube, often 1 or 3 of them imperfectly developed. Pistil consisting of a 2-celled and usually many-ovuled ovary, with a single style and an entire or 2-lobed stigma.

Corolla wheel-shaped, stamens 5. Verbascum, I

Corolla wheel-shaped or salver-shaped, nearly actinomorphic, stamens 2. Veronica, VI

Corolla 2-lipped, the mouth closed by a palate, tubular below, a spur at the base. Linaria, II

Corolla 2-lipped, the mouth closed by a palate, tubular below, a short, broad pouch at the base. Antirrhinum, III

Corolla decidedly 2-lipped.

- Stamens with anthers 2. Gratiola, V
- Stamens 4, with a fifth antherless filament. Pentstemon, IV
- Stamens 4, the anther cells unequal. Castilleja, VII
- Stamens 4, the anther cells equal. Pedicularis, VIII

I. VERBASCUM L.

Biennial; stem tall, erect. Leaves alternate. Flowers in spikes, racemes, or panicles. Calyx deeply 5-cleft. Corolla wheel-shaped, 5-lobed, the lobes nearly equal. Stamens 5, unequal, declined; some or all of the filaments bearded. Style flattened at the apex. Fruit a globose capsule; seeds roughened.*

1. **V. Blattaria** L. MOTH MULLEIN. Stem erect, slender, simple or sparingly branched, smooth below, downy above, 2–4 ft. high. Leaves oblong to lanceolate, acute at the apex, obtuse or truncate at the base, dentate to pinnately lobed, the lower petioled, the upper

sessile and clasping. Raceme long and loose, glandular-downy; pedicels bracted. Corolla white or yellow, marked with brown on the back, about 1 in. wide. Filaments all bearded with purple hairs. Capsule longer than the calyx. Common in fields and waste places. Naturalized from Europe.*

II. LINARIA Hill

Herbs, rarely shrubby. Lower leaves opposite, whorled or alternate. Flowers in bracted racemes or spikes, or axillary and solitary. Calyx 5-parted. Corolla 2-lipped, the tube spurred. Stamens 4, with sometimes a rudiment of a fifth. Stigma notched or 2-lobed. Capsule ovoid or globose; cells nearly equal.

1. **L. vulgaris** Hill. BUTTER AND EGGS, JACOB'S LADDER, WILD FLAX. A perennial, erect, smooth herb, with a bloom; stem 1–2 ft. high. Leaves linear or lanceolate, 1–3 in. long, often whorled. Racemes densely flowered. Sepals shorter than the spur. Corolla yellow, $\frac{3}{4}$–1 in. long; spur parallel to and as long as the tube; throat closed by a palate-like fold. Common in dry fields and pastures and along roadsides. Naturalized from Europe.

2. **L. canadensis** Dumont. TOADFLAX. Biennial; flowering stems erect, slender, rarely branched, smooth, 1–2 ft. high; sterile stems prostrate, with opposite or whorled leaves, 2–6 in. long. Leaves linear, entire, sessile. Racemes erect, slender; pedicels erect, as long as the calyx. Corolla small, blue and white, the spur thread-like, curved, longer than the pedicels. Capsule 2-valved, the valves 3-toothed. On dry or cultivated ground E.

III. ANTIRRHINUM L.

Annual or perennial herbs. Leaves entire, rarely lobed, the lower ones opposite, the upper alternate. Flowers axillary and solitary, or racemed and bracted. Calyx 5-parted. Corolla 2-lipped; the tube with a sac, the broad-bearded palate closing the throat. Stamens 4. Stigma with 2 short lobes. Capsule 2-celled, the upper cell opening by 1 pore, the lower by 2.

1. **A. majus** L. SNAPDRAGON. Perennial; stem erect, smooth below, glandular-downy above, 1–2 ft. high. Leaves linear to oblong-lanceolate, entire, smooth, sometimes fleshy, sessile or short-petioled. Flowers in a terminal raceme; pedicels short, stout, erect in fruit. Corolla $1\frac{1}{2}$–2 in. long, of many colors. Capsule oblique, the persistent base of the style bent forward. Common in gardens; cultivated from Europe, and often escaped.*

IV. PENTSTEMON Mitchell

Perennials, the stems branching from the base, unbranched above. Leaves opposite. Flowers usually showy, in a terminal panicle. Calyx of 5 nearly distinct sepals. Corolla tubular, the tube wide above and narrowed below; 2-lipped. Stamens 4 (2 long and 2 short), with a fifth antherless filament as long as the others, its upper half bearded. Capsule ovoid, acute.

1. P. hirsutus Willd. Stem somewhat sticky-downy, 1–2 ft. high. Leaves varying from oblong to lanceolate, 2–4 in. long, usually with small teeth. Flower cluster narrow. Corolla dingy violet, purplish, or whitish; the tube not much widened above, its throat nearly closed by a hairy palate. Sterile filament much bearded. Dry hillsides or stony ground.

2. P. gracilis Nutt. SLENDER BEARDTONGUE. Stem 6–18 in. high, smooth below but the flower cluster covered with glandular, sticky hairs. Basal leaves spatulate or oblong; stem leaves most of them linear-lanceolate. Corolla purple or whitish, $\frac{3}{4}$–1 in. long, the tube enlarged above and its throat entirely open. Sterile filament bearded above along half its length. On moist prairies W.

3. P. lævigatus Ait. Stem usually smooth except the flower cluster, 2–4 ft. high. Leaves shining, those of the stem ovate-lanceolate or broadly lanceolate, 2–5 in. long, with a somewhat heart-shaped, clasping base. Flower cluster broader than in No. 1. Corolla white or oftener purplish, suddenly widened above, the throat not closed. Sterile filament slightly bearded toward the top. In rich soil.

4. P. Digitalis Nutt. Much resembling No. 3, but taller, sometimes 5 ft. high. Corolla white, the tube abruptly widened. In fields and thickets; sometimes cultivated.

5. P. barbatus Roth. Stems slender and rod-like, 3–4 ft. high. Leaves lanceolate, entire. Flower cluster long and loosely flowered. Flowers showy, drooping. Corolla tube slender, scarlet, somewhat bearded in the throat. Sterile filament beardless. Cultivated from Mexico.

V. GRATIOLA L.

Low herbs, growing in wet or damp ground. Leaves opposite, sessile. Flowers axillary and solitary, peduncled. Calyx 5-parted, usually with 2 bractlets at the base. Corolla somewhat 2-lipped. Perfect stamens 2. Stigma enlarged or 2-lipped. Pod 4-valved, many-seeded.

1. G. virginiana L. Stem cylindrical, 4–10 in. long, branching from the base. Leaves $\frac{3}{4}$–$1\frac{1}{2}$ in. long, varying from lance-oblong to spatulate. Corolla pale yellow, tinged with red. Common in muddy soil, along brooksides, etc.

VI. VERONICA L.

Herbs or shrubs. Lower leaves or all the leaves opposite, rarely whorled. Flowers in axillary or terminal racemes, rarely solitary. Calyx usually 4-parted. Corolla wheel-shaped or somewhat bell-shaped; limb usually 4-cleft, spreading, the side lobes commonly narrower. Stamens 2, inserted on the corolla tube at the sides of the upper lobe, projecting. Stigma somewhat knobbed. Capsule generally flattened, often notched at the apex, 2-celled, few–many-seeded.

1. V. americana Schwein. BROOKLIME. A perennial, smooth herb, somewhat prostrate below but the upper parts of the stem erect, 8–15 in. high. Leaves 1–2 in. long, lance-ovate or oblong, serrate, short-petioled. Racemes 2–4 in. long, axillary and opposite. Corolla wheel-shaped, blue. Capsule swollen, roundish. Muddy soil about springs and brooks.

2. V. officinalis L. COMMON SPEEDWELL, GYPSY WEED. Perennial. Roughish-downy, with the prostrate stems spreading and rooting. Leaves wedge-oblong or nearly so, obtuse, serrate, somewhat petioled. Racemes dense, of many pale bluish flowers. Capsule rather large, inversely heart-shaped and somewhat triangular. Dry hillsides, open woods and fields.

3. V. serpyllifolia L. THYME-LEAVED SPEEDWELL. Perennial; smooth or nearly so; branching and creeping below, but with nearly simple ascending shoots, 2–4 in. high. Leaves slightly crenate, the lowest ones petioled and roundish, those farther up ovate or oblong, the uppermost ones mere bracts. Raceme loosely flowered. Corolla nearly white or pale blue, beautifully striped with darker lines. Capsule inversely heart-shaped, its width greater than its length. Damp, grassy ground; a common weed in lawns.

4. V. peregrina L. PURSLANE SPEEDWELL. A homely, rather fleshy, somewhat erect-branched annual weed, 4–9 in. high. Lowest leaves petioled, oblong, somewhat toothed; those above them sessile, the uppermost ones broadly linear and entire. Flowers solitary, inconspicuous, whitish, barely pediceled, appearing to spring from the axils of the small floral leaves. Corolla shorter than the calyx. Capsule roundish, barely notched, many-seeded. Common in damp ground, in fields and gardens.

VII. CASTILLEJA Mutis.

Herbs parasitic on the roots of other plants. Leaves alternate; the floral ones usually colored at the tip and more showy than the flowers. Flowers yellow or purplish in terminal leafy spikes. Calyx tubular, flattened, 2–4-cleft. Corolla tube included within the calyx; upper lip of the corolla very long, linear, arched, and inclosing the stamens, 2 of which are long and 2 short. Ovary many-ovuled.

1. **C. coccinea** Sprengel. SCARLET PAINTED CUP, PAINT BRUSH, INDIAN PINK, PRAIRIE FIRE, WICKAKEE. A hairy, simple-stemmed herb, annual or biennial. Root leaves clustered, obovate or oblong; stem leaves cut; floral leaves 3–5-cleft and bright scarlet (occasionally yellow) toward the tips, as though dipped in a scarlet dye. Calyx nearly as long as the pale yellow corolla, 2-cleft. The spikes are often very broad, making this one of the most conspicuous of our native flowers. Damp, sandy ground, or on bluffs near streams; sometimes in marshes.

2. **C. sessiliflora** Pursh. DOWNY PAINTED CUP. Perennial; stem leafy, 6–15 in. high, covered with ash-colored down. Lowest leaves linear and entire, upper ones usually deeply cleft into narrow segments; floral leaves green, like the upper stem leaves. Calyx lobes more deeply cleft on the lower than on the upper side, linear-lanceolate. Corolla yellowish, nearly 2 in. long; upper lip about twice the length of the lower one. On prairies W. and S.W.

VIII. PEDICULARIS L.

Perennial herbs, with the lower leaves pinnately cut and the floral ones reduced to bracts. Flowers spiked. Corolla markedly 2-lipped; the upper lip much flattened laterally and arched, the lower lip spreading, 3-lobed. Stamens 4, beneath the upper lip. Capsule 2-celled, tipped with an abrupt point, several-seeded.

1. **P. canadensis** L. COMMON LOUSEWORT. Hairy, with clustered simple stems, 1 ft. high or less. Leaves petioled, the lowermost ones pinnately parted, the others somewhat pinnately cut. Spike short, closely flowered, and leafy-bracted. Calyx split down the front. Corolla greenish-yellow and purplish, with its upper lip hood-like, curved under, and with 2 awl-like teeth near the end. Capsule flat, broadly sword-shaped. Knolls and openings among thickets.

91. BIGNONIACEÆ. Bignonia Family

Trees or shrubs, often twining or climbing, rarely herbs. Leaves usually opposite, without stipules. Flowers showy, zygomorphic. Corolla tubular, with a widened throat and a 5-lobed limb. Stamens usually 2 long and 2 short, or only 2. Ovary free from the calyx, 2-celled or rarely 1-celled, with many ovules. Fruit a capsule; seeds large, winged.

I. TECOMA Juss.

Woody vines, climbing by aërial rootlets. Leaves compound, odd-pinnate. Flowers large, in terminal clusters. Calyx bell-shaped, unequally 5-toothed. Corolla funnelform, enlarged above the calyx, 5-lobed, slightly 2-lipped. Stamens 4, 2 long and 2 short. Capsule slender, spindle-shaped, slightly compressed contrary to the partition, 2-valved, dehiscent. Seeds winged.*

1. T. radicans Juss. Trumpet Flower, Trumpet Creeper. Stems climbing high by numerous rootlets; bark shreddy. Leaves deciduous, petioled; leaflets 9–11, ovate to ovate-lanceolate, serrate, short-stalked, smooth or slightly downy. Flowers in short, terminal racemes or corymbs. Calyx tubular, $\frac{3}{4}$ in. long. Corolla 2–3 in. long, scarlet without, yellow within, the lobes spreading. Capsule 5–6 in. long, curved, often persistent through the winter. Seeds broadly winged. On borders of fields and in woods S.; often cultivated.*

II. CATALPA Scop.

Small trees. Leaves large, opposite, simple, petioled, deciduous. Flowers large and showy, in terminal panicles. Calyx irregularly 2-lipped. Corolla tubular-bell-shaped, oblique, 5-lobed, 2-lipped. Fertile stamens 2, sterile stamens 3, short. Fruit a linear, 2-valved, many-seeded capsule. Seeds winged.*

1. C. bignonioides Walt. Catalpa. A small tree with thin, rough gray bark, and light, soft but exceedingly durable wood. Leaves long-petioled, heart-shaped, entire or palmately 3-lobed, taper-pointed at the apex, palmately veined, downy. Branches of the panicle in threes; flowers large, 1–1$\frac{1}{2}$ in. long, white, variegated with yellow and purple. Corolla lobes undulate or crisped. Capsule

very slender, 1 ft. or more in length, pendulous. Seeds with long fringed wings. On margins of rivers and swamps S.; often cultivated.*

2. C. speciosa Warder. CATALPA. A tall tree with very durable wood. Leaves large, heart-shaped, taper-pointed. Corolla about 2 in. long, almost white, but slightly spotted; tube inversely conical; limb somewhat oblique, its lower lobe notched. Pod rather stout. Rich, damp woods, especially S. W.; often cultivated.

III. BIGNONIA L.

Woody vines. Leaves opposite, compound, usually tendril-bearing. Flowers large, in axillary clusters. Calyx cup-shaped, truncate, or undulate-toothed. Corolla spreading-tubular, somewhat 2-lipped, the lobes rounded. Stamens 4, 2 long and 2 short. Capsule linear, flattened parallel with the partition, the two valves separating from the partition at maturity; seeds flat, broadly winged.*

1. B. capreolata L. CROSS VINE. Stem climbing high, a transverse section of the older stems showing a conspicuous cross formed by the 4 medullary rays; branches smooth. Leaves evergreen, petioled; leaflets 2, ovate, taper-pointed with a blunt apex, heart-shaped at the base, entire, stalked; upper leaflets transformed into branching tendrils. Flowers numerous, short-peduncled. Corolla 2 in. long, reddish-brown without, yellow within. Capsule 6 in. long, flat, the valves with a prominent central nerve; seeds broadly winged on the sides, short-winged on the ends. Common in woods S.*

92. OROBANCHACEÆ. BROOM RAPE FAMILY

Leafless brownish root parasites; rootstock often tuberous, naked or scaly; stem usually stout, solitary, scaly. Flowers spiked or racemed. Sepals 4–5, free from the ovary. Corolla hypogynous, not actinomorphic, the tube curved, the limb 2-lipped. Stamens 4 (2 long and 2 short), inserted on the corolla tube; anthers 2-celled, the cells spurred at the base. Ovary 1-celled, of 2 carpels; style simple; stigma 2-lobed; ovules many. Capsule 1-celled, 2-valved, few–many-seeded; seeds very small.

I. CONOPHOLIS Wallr.

Stems often clustered, stout, covered with scales which overlap, the uppermost ones each with an axillary flower,

thus forming a spike. Calyx irregularly 4–5-cleft, split down the lower side. Corolla swollen below, decidedly 2-lipped, the upper lip arched. Stamens projecting.

1. C. americana Wallr. SQUAWROOT, CANCER ROOT. Stems 3–6 in. high, yellowish or yellowish-brown. Flowers numerous, inconspicuous. Corolla dirty white or pale brown. In oak woods; not very common.

II. OROBANCHE L. (THALESIA)

Brownish or whitish plants, with naked scapes borne on scaly, mostly underground, stems. Calyx regular, 5-cleft. Corolla 5-lobed, slightly irregular. Stamens not projecting from the corolla tube.

1. O. uniflora L. ONE-FLOWERED CANCER ROOT. Slightly covered with clammy down. Stems very short-branched, each with 1–3 1-flowered scapes 3–5 in. high. Calyx lobes lance-awl-shaped, half as long as the corolla. Corolla yellowish-white, veiny, purple-tinged; palate with 2 yellow bearded ridges. Damp woods.

2. O. fasciculata Nutt. Stem scaly, upright, 3–4 in. high above ground and generally longer than the numerous 1-flowered peduncles. Calyx lobes short, triangular. Parasitic on wild species of *Artemisia*, etc., in sandy and loamy soil N.W. and W.

93. ACANTHACEÆ. ACANTHUS FAMILY

Herbs or shrubs. Leaves opposite or whorled, without stipules. Flowers zygomorphic, usually with large bracts. Calyx of 4 or 5 unequal segments which considerably overlap each other. Corolla 4–5-parted and usually more or less 2-lipped. Stamens usually 2 long and 2 short, sometimes only 2. Ovary free from the calyx. Fruit usually a capsule. Seeds not winged. A large family, mostly tropical, with only a few insignificant wild species in the northern United States.

I. DIANTHERA L.

Perennial herbs; stem smooth. Leaves opposite, entire or toothed. Flowers axillary, solitary or clustered, zygomorphic. Calyx 5-parted. Corolla 2-lipped; upper lip erect, concave, entire or notched; the lower prominently veined, spreading,

3-lobed. Stamens 2, inserted in the throat of the corolla. Ovary 2-celled, 4-ovuled; style simple, acute. Capsule flattened, narrowed below into a little stalk.*

1. **D. americana** L. Water Willow. Stem erect, slender, 2–3 ft. high. Leaves lanceolate to linear-lanceolate, taper-pointed at the apex, narrowed below to the sessile or short-petioled base. Flowers bracted, in short spikes, on peduncles as long as the leaves. Corolla pale blue or purple, the tube as long as the lips, lower lip wrinkled. Capsule about the length of the calyx. In water, S.*

II. RUELLIA L.

Perennial herbs; stems swollen at the joints and often between them, somewhat 4-angled. Leaves sessile or short-petioled, mostly entire. Flowers axillary, solitary or clustered, showy, white, blue, or purple. Calyx 2-bracted, 5-parted, the divisions linear and awl-shaped. Corolla tube slender, often much elongated, the limb spreading, nearly equally 5-lobed. Stamens 4 (2 long and 2 short), included or slightly projecting. Style slender. Capsule slender, narrowed below, 4–12-seeded.*

1. **R. ciliosa** Pursh. Hairy Ruellia. Stem erect, rather stout, often few-branched above, covered with white hairs, 4–30 in. high. Leaves oblong to ovate, acute or obtuse at the apex, narrowed and mostly sessile at the base, hairy-fringed. Flowers pale blue, solitary or 2–3 together. Calyx lobes bristle-shaped, half the length of the corolla tube. Tube of the corolla 2 in. long. Capsule shorter than the calyx, smooth, 8–12-seeded. A very variable species, the flowers often without a corolla. In dry woods and fields S.*

2. **R. strepens** L. Smooth Ruellia. Stem erect, slender, usually simple, smooth or hairy, 1–3 ft. high. Leaves ovate to oblong, acute at the apex, narrowed below into a short petiole. Flowers solitary or in small clusters, sessile or short-peduncled. Calyx lobes shorter than the tube of the corolla, downy or fringed. Corolla blue, the tube 1½–2 in. long, the limb 1–1½ in. wide. Capsule usually longer than the calyx, smooth, 8–12-seeded. The later flowers often without a corolla. On rich, dry soil.*

94. PLANTAGINACEÆ. Plantain Family

Annual or perennial scape-bearing herbs. Leaves usually all basal, with parallel ribs. Flowers small, green, usually

spiked, regular and bisexual (Fig. 28). Sepals 4, persistent. Corolla hypogynous, salver-shaped, thin and dry; lobes 4, spreading. Stamens 4, usually inserted on the corolla tube; filaments thread-like; anthers large and versatile. Ovary free, usually 2–4-celled; style thread-like. Fruit a 1–4-celled, 1 or more seeded membranous capsule, which splits open transversely, the top coming off like a lid.

FIG. 28. Flowers of plantain (*Plantago lanceolata*), six times natural size

A, earlier stage, pistil mature, stamens not yet appearing outside the corolla; *B*, later stage, pistil withered, stamens mature

PLANTAGO L.

Characteristics of the genus as given above for the family.

1. P. major L. PLANTAIN. Perennial, from a very short rootstock. Leaves ovate to oval, strongly 5–9-ribbed, acute or obtuse at the apex, rounded at the base into a long, concave petiole, entire or toothed, smooth or slightly downy. Scape taller than the leaves, downy, spike densely flowered; bracts short, ovate. Flowers perfect. Stamens 4, projecting. Capsule ovoid, about twice the length of the calyx, 5–16-seeded; seeds angled and with a netted outer coat. Common in dooryards.*

2. P. Rugelii Decaisne. Leaves as in *P. major*, but smaller and thinner. Spikes less dense, usually drawn out to a slender point. Capsule 4–10-seeded; seeds oval, the outer coat not netted. In fields, woods, and waste ground.

3. P. lanceolata L. RIB GRASS. Biennial or perennial; soft-hairy or nearly smooth. Leaves numerous, lanceolate to elliptical, acute, long-petioled, strongly 3–5-ribbed, entire or toothed. Scapes much longer than the leaves, striate-angled, 1–2 ft. high; spike short and dense. Bracts and sepals ovate. Corolla smooth. Capsule longer than the calyx, 2-seeded. Naturalized from Europe; common in meadows.*

4. P. Purshii R. & S. Annual. White-woolly or silky. Scapes slender; leaves linear, usually 3-nerved; spikes dense, cylindrical, and very woolly; bracts stiff, as long as the flowers or slightly longer. Capsule 2–4-seeded, somewhat longer than the calyx. On dry prairies and plains W. and S.W.

5. P. aristata Michx. LARGE-BRACTED PLANTAIN. Annual. Leaves broadly linear, entire or sparingly and finely toothed, narrowed below into a margined petiole, smooth or silky-downy. Scape longer than the leaves, 6–10 in. high; spike dense. Bracts linear, $\frac{1}{2}$–1 in. long. Stamens 4. Capsule 2-seeded, longer than the calyx. Common on dry soil.*

6. P. heterophylla Nutt. MANY-SEEDED PLANTAIN. Annual. Leaves linear, fleshy, entire or with a few spreading teeth, smooth or slightly downy. Scapes slender, 3–6 in. high; spike very slender, many-flowered, the lower flowers often scattered. Bracts ovate, longer than the sepals. Stamens 2. Capsule twice the length of the calyx, many-seeded. Common in cultivated ground, especially S.*

95. RUBIACEÆ. MADDER FAMILY

Herbs, shrubs, or trees. Leaves opposite and entire, with stipules between them, or appearing whorled since the stipules resemble the leaves. Flowers epigynous, always bisexual, frequently dimorphous (as in *Houstonia, Mitchella*, and *Bouvardia*). Limb of the calyx 3–6-toothed. Corolla regular, inserted on the calyx-tube, as many-lobed as the calyx. Stamens equal in number to the divisions of the corolla. Ovary 2 or more celled. A very large and important family, of which many of the noteworthy species, for instance the coffee shrub and the cinchona tree, are natives of warm or tropical climates.

I. GALIUM L.

Annual or perennial herbs; stems slender, 4-angled. Leaves appearing whorled. Flowers small, in axillary or terminal cymes or panicles, bisexual or rarely diœcious. Calyx tube short, the teeth minute or wanting. Corolla wheel-shaped, 3–4-lobed. Stamens 3–4, short. Ovary 2-celled; styles 2, short, united below. Fruit 2 united, sometimes fleshy, 1-seeded carpels, which do not split open.*

1. **G. Aparine** L. Goose Grass. Annual; stem weak, decumbent, sharply 4-angled and with backward-pointing prickly hairs, widely branched, 2–4 ft. long. Leaves 6–8 in a whorl, oblanceolate, prickly-hairy on the margins and midrib. Peduncles axillary, longer than the leaves, 1–3-flowered; flowers white. Fruiting pedicels erect; fruit dry, covered with hooked bristles. In waste places.*

2. **G. circæzans** Michx. Wild Licorice. Perennial; stems several, erect, smooth or downy, 12–18 in. high. Leaves 4 in a whorl, oval to ovate, obtuse at the apex, strongly 3-nerved, downy. Cymes long-peduncled, repeatedly branched. Flowers nearly sessile, greenish-purple; pedicels at length recurved. Fruit with hooked bristles. In dry, open woods S. Easily recognized by the sweet, licorice-like taste of the leaves.*

3. **G. boreale** L. Northern Bedstraw. Perennial; stem smooth, erect, 1–2 ft. high. Leaves in fours, linear-lanceolate, 3-nerved. Flowers bright white, in compact cymes, grouped in a dense panicle. Fruit usually with minute bristles. In rocky soil along banks of streams, especially N.

4. **G. concinnum** T. & G. Shining Bedstraw. Stems slender, smooth, shining, commonly much branched, 6–12 in. high, often with the angles minutely roughened. Leaves usually in sixes, linear or nearly so, often slightly cuspidate. Flowers small, white, in open cymes. Fruit small, smooth. Dry hills and woodlands.

5. **G. asprellum** Michx. Rough Bedstraw. Perennial; stem branching, weak, 3–5 ft. long, often reclining on bushes, with many hooked prickles directed backwards. Leaves usually in sixes, or on the branches in fours or fives, narrowly oval to lanceolate or oblanceolate, cuspidate, with midribs and margins almost prickly. Flowers white, in several–many-flowered cymes. Fruit smooth. In rich, moist soil.

6. **G. triflorum** Michx. Perennial; stems reclining or prostrate, angles rough-bristly. Leaves mostly in sixes, lance-oblong, mucronate. Flowers usually in threes, on slender peduncles. Woodlands, especially N.

7. **G. hispidulum** Michx. Bedstraw. Perennial, from yellow roots; stems diffusely branched, smooth or slightly roughened, downy at the joints, erect or decumbent, 1–2 ft. long. Leaves 4 in a whorl, narrowly oval, acute, rough on the margins and mid-vein. Peduncles 1–3-flowered; flowers white; pedicels becoming reflexed. Fruit a bluish-black, roughened berry. On dry, sandy soil.*

II. MITCHELLA L.

A pretty, trailing, evergreen herb. Leaves roundish-ovate, petioled. Flowers fragrant, white or pinkish, dimorphous,

growing in pairs, joined by their ovaries. Calyx 4-toothed. Corolla funnel-shaped, with the lobes bearded within. Stamens 4, short. Style 1; stigmas 4, slender. Fruit double, composed of the united ovaries; really a drupe, containing 8 seed-like, bony nutlets, ripening into tasteless scarlet berries, which cling to the plant through the winter.

1. **M. repens** L. PARTRIDGE BERRY, SQUAW VINE, TWO-EYE BERRY. Common in dry woods, especially under evergreen coniferous trees.

III. BOUVARDIA Salisb.

Smooth perennials. Leaves lanceolate, thickish. Calyx 4-lobed, the divisions slender. Corolla with a long and narrow or rather trumpet-shaped tube, and spreading, 4-lobed limb. Anthers 4, inserted in the throat of the corolla, almost sessile. Stigmas 2, flat. Capsule globular, 2-celled, many-seeded. Flowers dimorphous.

1. **B. triphylla** Salisb. THREE-LEAVED BOUVARDIA. Somewhat shrubby. Leaves nearly smooth, ovate or oblong-ovate; the lower ones in threes, the upper ones sometimes in pairs. Corolla scarlet and slightly downy outside.

2. **B. leiantha** Benth. DOWNY-LEAVED BOUVARDIA. Leaves rather downy. Corolla deep scarlet, smooth outside.

Both species cultivated from Mexico; in greenhouses.

IV. HOUSTONIA L.

Annual, biennial, or perennial herbs; stems erect or diffuse. Leaves entire; stipules often only a line connecting the bases of opposite leaves. Flowers small, solitary or clustered, dimorphous, the stamens projecting and the style short in one form, while in the other the stamens are short and the style projecting. Calyx 4-toothed, persistent. Corolla wheel-shaped to funnelform, 4-lobed. Stamens 4. Ovary 2-celled; style slender; stigmas 2. Fruit a 2-celled, few–many-seeded capsule, opening at the apex, free from the calyx.*

1. **H. cœrulea** L. BLUETS, INNOCENCE, QUAKER LADIES, EYE-BRIGHT. Perennial, from very slender rootstocks; stems tufted, erect, smooth, forking, 3–6 in. high. Leaves sessile, often hairy-fringed, the lower spatulate, the upper lanceolate. Flowers solitary,

on slender axillary peduncles. Calyx small. Corolla salverform, blue or white, yellow in the throat, smooth. Capsule laterally compressed, 2-lobed, shorter than the calyx. Common on open ground.*

2. H. patens Ell. SMALL BLUETS. Annual; stem erect, branched at the base, forking above, smooth, 2–4 in. high. Lower leaves oval to ovate, petioled, the upper narrower and sessile. Flowers solitary, on slender, axillary peduncles, blue or white. Calyx small. Lobes of the corolla about as long as the tube. Stamens and style projecting or included. Capsule compressed, as long as the calyx. Common on dry, open ground.*

3. H. purpurea L. LARGE BLUETS. Perennial; stem stout, erect, simple or branched, smooth or downy, 4-angled, 6–12 in. high. Leaves ovate to ovate-lanceolate, sessile or short-petioled, 3–5-nerved, often hairy-fringed on the margins. Flowers in terminal cymes, purple to nearly white. Corolla funnelform, the tube longer than the limb, hairy within. Stamens and style projecting or included. Capsule compressed-globose, much shorter than the calyx. In dry, open woods.*

4. H. longifolia Gaertn. LONG-LEAVED BLUETS. Perennial; stem erect, branched, smooth, 4-angled, 8–12 in. high. Leaves sessile, the lower oblanceolate or spatulate, the upper linear, 1-nerved. Corymbs terminal, few-flowered. Corolla light purple to white, the lobes much shorter than the tube. Capsule compressed-globose, nearly as long as the calyx. In dry, open woods.*

96. CAPRIFOLIACEÆ. HONEYSUCKLE FAMILY

Mostly shrubs. Leaves opposite, without true stipules. Flowers epigynous, often zygomorphic. Corolla tubular or wheel-shaped. Stamens usually as many as the corolla lobes and inserted on the corolla tube. Fruit a berry, drupe, or capsule.

I. DIERVILLA Mill.

Low, upright shrubs. Leaves taper-pointed, serrate. Flowers in loose terminal or axillary clusters or cymes. Calyx with a limb of 5 linear divisions. Corolla funnel-shaped, almost regularly 5-lobed. Stamens 5. Ovary slender, 2-celled, ripening into a 2-valved, many-seeded pod.

1. D. Lonicera Mill. COMMON BUSH HONEYSUCKLE. Bushy, 1–4 ft. high. Leaves ovate or oblong-ovate, petioled. Peduncles 1–3-flowered. Pods tapering to a slender point. Rocks, especially N.

2. D. japonica DC. WEIGELA. A stout, branching shrub, 3–6 ft. high. Leaves broadly oval, acute at the apex, rounded at the base, coarsely serrate, rough above, downy beneath, short-petioled. Flowers spreading, funnelform, rose color, 1–1½ in. long. Calyx lobes deciduous. Corolla downy without, the lobes spreading. Capsule oblong or spindle-shaped. Seeds with netted wings. Introduced from Japan; common in cultivation.*

II. LONICERA L.

Shrubs or woody vines. Leaves simple, usually entire, those of a pair often appearing as if joined together at the base, so that the stem seems to rise through them. Calyx tube ovoid, 5-toothed. Corolla tubular to bell-shaped, often knobbed at the base or 2-lipped. Stamens 5. Ovary 2–3-celled, ovules several in each cell; style slender; stigma knobbed. Fruit a 1–3-celled, 1–few-seeded berry.*

A

More or less upright bushes, not climbing.

1. L. tatarica L. TARTARIAN HONEYSUCKLE. A branching shrub, 5–8 ft. high. Leaves oval or ovate, heart-shaped, shining. Flowers many, showy, rose-colored. Fruit consisting of 2 red berries; somewhat united below at maturity. Cultivated from Asia.

2. L. canadensis Marsh. EARLY FLY HONEYSUCKLE. A straggling bush, 3–5 ft. high. Leaves ovate or oval, slightly heart-shaped, thin, at first downy beneath. Flowers straw-yellow, on short, slender peduncles. Corolla lobes nearly equal; tube pouched at the base. Fruit 2 separate red berries.

B

Stems twining.

3. L. japonica Thunb. JAPAN HONEYSUCKLE. Stem twining high; young branches downy. Leaves ovate to oblong, entire, smooth above, pale and downy beneath, all short-petioled. Peduncles axillary, 2-bracted, 2-flowered. Flowers white or pink, fading to yellow, 2-lipped, the lips nearly as long as the downy tube. Stamens and style projecting. Fruit black. Common in cultivation; introduced from Japan.*

4. L. sempervirens L. CORAL HONEYSUCKLE, TRUMPET HONEYSUCKLE. Stem twining high. Leaves evergreen (in the South), oval to oblong, obtuse, entire, smooth above, pale and often downy

beneath; the lower petioled, the upper pair nearly semi-orbicular and joined at the base. Flowering spikes terminal, bearing several whorls. Corolla about 2 in. long, slender, smooth; the limb short, nearly equally 5-lobed, scarlet without, bright yellow within. Stamens slightly projecting; fruit red. On low ground; often cultivated.*

5. L. Caprifolium L. EUROPEAN HONEYSUCKLE. A moderately high-climbing shrub. Leaves smooth and deciduous, several of the upper pairs united at their bases to form a flattish disk or somewhat cup-shaped leaf. Flowers in a single terminal whorl, very sweet-scented. Corolla whitish, red, or yellow, 2-lipped, with the lips recurved. Cultivated from Europe.

6. L. Sullivantii Gray. YELLOW HONEYSUCKLE. Stem somewhat twining. Leaves oval to obovate, obtuse, entire, green above, with a bloom beneath, the lower short-petioled, the upper sessile or joined at the base. Flowers in crowded, terminal whorls, bright yellow, fragrant. Corolla tube slender, 1–1½ in. long, bilabiate, 4-lobed, pubescent within. Stamens and style projecting. On river banks and hillsides; often cultivated.*

III. SYMPHORICARPOS Ludwig

Shrubs. Leaves short-petioled, deciduous. Flowers in axillary clusters. Calyx tube globose, 4–5-toothed. Corolla bell-shaped, 4–5-lobed, sometimes knobbed at the base, smooth or hairy within. Stamens 4–5. Ovary 4-celled; 2 of the cells with a single fertile ovule in each, the other cells with several abortive ovules; style slender; stigma knobbed or 2-lobed. Fruit a 4-celled, 2-seeded berry.*

1. S. racemosus Michx., var. **lævigatus**. SNOWBERRY. An ornamental shrub, 2–3 ft. high. Flowers in loose terminal racemes, which are often leafy. Corolla bell-shaped, much bearded inside, pinkish-white. Stamens and style not projecting. Berries rather large, snow-white, remaining long on the branches. Rocky banks, often cultivated.

IV. LINNÆA L.

A very small, slender, creeping evergreen shrub; branches inclined, ending in a slender, erect, 2-flowered peduncle. Leaves opposite, without stipules. Flowers nodding, on slender pedicels, with 2 bractlets. Calyx tube ovoid; limb 5-lobed. Corolla nearly bell-shaped, 5-lobed. Stamens 4, inserted near the base of the corolla; 2 of them longer than the other 2.

Ovary 3-celled; style thread-like; stigma knobbed; ovules many in 1 cell, solitary in the 2 others. Fruit nearly globose, 1-seeded.

1. **L. borealis** L. TWIN FLOWER. A beautiful, delicate plant. Corolla pale pink, very fragrant. Moist woods, in moss and cold bogs N.

V. TRIOSTEUM L.

Coarse, hairy, perennial herbs. Leaves large, those of each pair somewhat joined at the base, so that the stem appears to rise through them. Calyx tube ovoid; divisions of the limb leaf-like, lance-linear, persistent. Corolla knobbed at the base, nearly equally 5-lobed. Ovary usually 3-celled, ripening into a drupe with 3 nutlets.

1. **T. perfoliatum** L. TINKER WEED, WILD COFFEE, FEVERWORT, HORSE GENTIAN. Stem unbranched, soft-hairy, 2–4 ft. high. Leaves spatulate-ovate, abruptly narrowed at the base, 4–7 in. long and 2–4 in. wide, bordered with a fringe of hairs. Flowers dark brownish-purple. Corolla about $\frac{1}{2}$ in. long, sticky-downy. Fruit ellipsoidal, orange-colored when ripe. Common along fence rows and in rocky woods.

VI. VIBURNUM L.

Shrubs or small trees. Leaves simple, entire, dentate or lobed, with or without stipules. Flowers small, white, in terminal cymes; the outer flowers of the cyme sometimes greatly enlarged and sterile. Calyx tube very small, 5-toothed. Corolla wheel-shaped or bell-shaped, 5-lobed. Stamens 5, inserted in the tube of the corolla. Ovary 1–3-celled, 1–3-ovuled, but only 1 ovule maturing; style short, 3-lobed. Fruit a 1-seeded drupe, with soft pulp.*

A

Flowers around the margin of the cyme without stamens or pistils, large and showy.

1. **V. alnifolium** Marsh. HOBBLEBUSH, WITCH HOBBLE. A shrub about 5 ft. high, with the branches reclining and often rooting and forming loops (whence the popular names). Leaves very large, roundish, abruptly taper-pointed, serrate, with a rusty down on the petioles and veinlets. Cymes very broad and showy. Fruit red, not eatable.

2. V. Opulus L., var. **americanum.** CRANBERRY TREE, HIGH-BUSH CRANBERRY. A handsome, upright shrub. Leaves 3–5-ribbed and 3-lobed. Fruit bright red, juicy, very acid, and used as a substitute for cranberries. Common N. The form known as "snowball," with all the flowers showy and sterile, is cultivated from Europe.

B

Flowers all small and bisexual.

3. V. acerifolium L. MAPLE-LEAVED ARROWWOOD. A slender shrub, 3–6 ft. high. Leaves broadly ovate to heart-shaped, palmately veined and 3-lobed, serrate or nearly entire, petioled, downy, becoming smooth above. Cymes peduncled, about 7-rayed, 2–3 in. wide; sterile flowers none. Fruit oval, black; stone flat, 2-ridged on the edges. In dry, open woods.*

4. V. dentatum L. ARROWWOOD. A shrub 8–15 ft. high. Leaves broadly ovate to oval, acute at the apex, rounded or heart-shaped at the base, coarsely dentate, smooth above, hairy in the axils of the veins beneath, short-petioled. Cymes long-peduncled, 7-rayed, 2–3 in. wide; sterile flowers none. Calyx smooth. Fruit globose, dark blue; stone compressed, grooved on one side. In rich, damp soil.*

5. V. nudum L. WITHE-ROD. A shrub 8–12 ft. high. Leaves ovate to lanceolate, entire or slightly toothed, acute at both ends, thick, smooth above, the veins prominent beneath; petiole short. Cymes short-peduncled, 5-rayed; sterile flowers none. Fruit ovoid, blue. Common in swamps.*

6. V. Lentago L. NANNYBERRY, SHEEPBERRY. A shrub or small tree, sometimes 30 ft. high. Leaves ovate, sharply serrate, taper-pointed, usually smooth on both sides. Flower clusters large compound cymes. Fruit oval, ½ in. or more long, bluish-black, with a bloom, eatable. In woods and on banks of streams.

7. V. prunifolium L. BLACK HAW. A small tree, 15–20 ft. high. Leaves oval to ovate, acute or obtuse at each end, finely and sharply serrate, smooth and shining above, often slightly downy beneath; petioles dilated and rusty-downy. Cymes sessile, large, 4–5-rayed; sterile flowers none. Fruit oval, bluish-black, eatable. In rich, moist woods.*

VII. SAMBUCUS L.

Shrubs with odd-pinnate leaves. Calyx limb minute or wanting. Flowers very many, small, white, in compound cymes. Corolla with a small, somewhat urn-shaped tube, and a flattish, spreading, 5-cleft limb. Stamens 5. Stigmas 3, sessile. Fruit a globular, pulpy drupe, 3-seeded, appearing like a berry.

1. **S. canadensis** L. COMMON ELDER. Stems 5–10 ft. high, with a thin cylinder of wood surrounding abundant white pith. Leaflets 5–11, oblong, taper-pointed, smooth. Cymes flat and often very large. Fruit purplish-black, insipid or almost nauseous, but somewhat used in cookery.

2. **S. racemosa** L. RED-BERRIED ELDER. More woody, with brown pith. Leaflets fewer, downy beneath, especially when young. Cymes panicled and somewhat pyramidal. Fruit scarlet.

97. VALERIANACEÆ. VALERIAN FAMILY

Herbs, rarely shrubs. Leaves opposite, without stipules. Flowers epigynous, small, usually not actinomorphic, in forking cymes. Corolla funnel-shaped, the base often with a sac or spur. Stamens 1–3 or 5, inserted at the base of the corolla tube; filaments slender, anthers versatile. Ovary cells 3; two of them not ovule-bearing, the third with a single ovule hanging from the top; style thread-like; stigma blunt or 2–3-lobed. Fruit small, not splitting open.

I. VALERIANA L.

Perennial, rarely annual, herbs. Basal leaves crowded; stem leaves opposite or whorled, entire or pinnately cut. Flowers in corymbed, headed, or panicled cymes. Limb of the calyx consisting of several plumy bristles. Lobes of the corolla 5 or rarely 3–4, unequal. Stamens 3. Stigma knobbed. Fruit flattened, ribbed, 1-celled, 1-seeded.

1. **V. edulis** Nutt. An upright, straight-stemmed plant, 1–4 ft. high. Leaves all thickish and closely fringed with short hairs; root leaves linear-spatulate or lanceolate-spatulate, entire; stem leaves pinnately parted, the 3–7 divisions long and narrow. Flowers almost diœcious in a long, interrupted panicle. Corolla whitish. Root long and stout, eaten by Indians. Low ground and wet prairies, especially N.W.

2. **V. officinalis** L. GARDEN VALERIAN. Plant smooth or hairy below, strong smelling. Rootstock short. Leaves all pinnate; basal leaves long-petioled, soon withering; stem leaves 2–5 in. long, sessile, the leaflets lanceolate, entire or serrate. Corolla pale pink. Rootstocks strong-scented, used in medicine. Cultivated from Europe.

II. VALERIANELLA Hill

Annual herbs; stem forking regularly. Leaves opposite, entire or dentate. Flowers in crowded, terminal, bracted cymes. Calyx limb toothed or wanting. Corolla white or purplish, funnelform, 5-lobed. Stamens 3. Style 3-lobed. Fruit 3-celled, 1-seeded.*

1. V. Locusta Betcke. LAMB LETTUCE. Stem erect, smooth, or downy at the nodes, many times forked, 9–12 in. high. Basal leaves tufted, spatulate to obovate, entire; the upper lanceolate, dentate, sessile. Cymes short-peduncled, bracts linear. Flowers pale blue. Fruit compressed, oblique. On rich soil in waste places. Sometimes cultivated for salad. Introduced from Europe.*

2. V. radiata Dufr. CORN SALAD. Stem erect, smooth above, downy below, 2–4 times forked, 8–12 in. high. Lower leaves spatulate, entire; the upper lanceolate, clasping at the base, dentate. Cymes compact; bracts lanceolate. Flowers white. Fruit ovoid, downy, furrowed. On damp soil.*

98. CUCURBITACEÆ. GOURD FAMILY

Somewhat succulent, tendril-bearing, prostrate or climbing, herbaceous plants. Leaves alternate, with stipules. Flowers epigynous, diœcious or monœcious, often sympetalous. Calyx limb (if present) 5-lobed. Corolla usually 5-lobed and with its tube more or less united with the calyx tube. Stamens perigynous or borne upon the corolla; the anthers usually joined in long, serpentine ridges. Ovary 3-celled; stigmas 2 or 3. Fruit generally a pepo (like the melon, squash, and pumpkin), but sometimes dry. Seeds commonly large and flat. A large family, mostly of tropical plants, many with eatable fruit, but some species poisonous.

I. CUCURBITA L.

Annual or perennial herbs; stem trailing or climbing, 2–20 ft. long. Leaves angular-lobed; tendrils branching. Flowers monœcious, solitary or in small clusters. Calyx 5-toothed, the limb deciduous. Corolla bell-shaped, 5-lobed. Staminate flowers with 3 stamens and no pistil; pistillate flowers with 1 pistil and 3 imperfect stamens. Style short; stigmas 3–5, each 2-lobed. Fruit 1-celled, with numerous seeds on the 3 parietal placentæ.*

1. **C. fœtidissima** HBK. Missouri Gourd. Stem stout, rough and hairy. Root very large, carrot-shaped. Leaves thick, triangular heart-shaped. Flowers 3–4 in. long. Fruit globose or somewhat obovoid, 2–3 in. in diameter. Dry soil W. and S.W.

2. **C. Melopepo** L. Summer Squash. Stem rough-hairy, angled, 2–5 ft. long. Leaves broadly heart-shaped, angularly 3–5-lobed, rough. Flowers yellow, short-peduncled. Fruit roundish, longitudinally compressed, the margin smooth, wavy, or tubercular. Common in cultivation.*

3. **C. verrucosa** L. Crookneck Squash. Stem rough-hairy, angled and striate, 5–10 ft. long. Leaves cordate, deeply 5-lobed, very rough, long-petioled. Flowers light yellow, long-peduncled. Fruit clavate, the base often slender and curved, smooth or tuberculate, very variable. Common in cultivation.*

II. CUCUMIS L.

Annual herbs; stems trailing, usually shorter and more slender than in the preceding genus; tendrils not forked. Leaves varying from entire or nearly so to deeply cut. Sterile flowers in clusters, fertile ones solitary in the leaf axils. Corolla of 5 acute petals, which are but little joined at the base. Stamens not evidently united. Style short; stigmas 3, each 2-lobed. Fruit rather long. Seeds not large, lance-oblong, not margined.

1. **C. sativus** L. Cucumber. Leaves somewhat lobed, the middle lobe largest. Fruit more or less covered when young with rather brittle, blackish prickles, which fall off as it ripens. Cultivated from S. Asia. [Other varieties of the genus *Cucumis* are the muskmelon, cantaloupe, and nutmeg melon. Other commonly cultivated genera are *Citrullus*, the watermelon, and *Lagenaria*, the bottle gourd. Two wild genera, *Echinocystis*, the wild cucumber, and *Sicyos*, the star cucumber, which blossom through the summer and autumn, are common in the northern states and the Middle West.]

99. CAMPANULACEÆ. Campanula Family

Herbs, with milky juice. Leaves alternate, without stipules. Flowers epigynous, actinomorphic, not clustered. Calyx 5-lobed. Corolla regular, bell-shaped, 5-lobed. Stamens 5, usually free from the corolla and not united. Style 1, usually hairy above; stigmas 2 or more. Fruit a capsule, 2 or more celled, many-seeded.

I. SPECULARIA Fabricius

Annual; stems slender, angled. Leaves entire or toothed. Flowers axillary, regular, solitary or in small clusters, sessile, bracted. Calyx tube slender, 3–5-parted. Corolla wheel-shaped, 5-lobed. Stamens with the filaments flattened and shorter than the anthers. Ovary 3-celled, many-ovuled; stigmas 3. Fruit a prismatic, 3-celled, many-seeded capsule.*

1. S. perfoliata A. DC. SPECULARIA. Stem erect, simple or branched from the base, angles roughened, 10–20 in. high. Leaves ovate to lanceolate, acute at the apex, sessile, crenate or entire, the upper bract-like. Flowers solitary or in pairs. Corolla blue, often wanting. Capsule cylindrical, smaller above. In waste places.*

II. CAMPANULA L.

Annual, biennial, or perennial herbs. Flowers solitary, racemed or spiked, regular, blue or white. Calyx 5-lobed or parted. Corolla wheel-shaped to bell-shaped, 5-lobed. Stamens 5, free from the corolla, distinct; filaments dilated at the base. Ovary 3–5-celled, many-ovuled; style 3-parted. Capsule short, bearing the persistent calyx lobes at its apex, many-seeded, splitting open on the sides.*

1. C. americana L. TALL BELLFLOWER. Annual or biennial. Stem erect, usually unbranched, 3–6 ft. high. Leaves varying from ovate to lanceolate, serrate, $2\frac{1}{2}$–6 in. long. Spike 1–2 ft. long. Corolla wheel-shaped, light blue, about 1 in. in diameter. Moist, rich soil, especially in thickets.

2. C. rotundifolia L. HAREBELL. A slender, smooth, branching perennial, 5–12 in. high. Root leaves broadly ovate-heart-shaped, generally somewhat crenate, soon withering; stem leaves varying from linear to narrowly lanceolate, entire. Pedicels slender; flowers solitary or somewhat racemed, the buds erect but the fully opened flower drooping. Calyx teeth erect, awl-shaped. Corolla bell-shaped, $\frac{1}{3}$–1 in. long, its lobes short and recurved. Rocky hillsides, especially N.

3. C. aparinoides Pursh. MARSH BELLFLOWER. Stem angular, unbranched, slender, weak, and leaning on the grass among which it usually grows, the angles clothed with minute, backward-pointing prickles. Leaves lance-linear, nearly entire. Flowers terminal, about $\frac{1}{3}$ in. long, white. Corolla bell-shaped. Wet meadows, in tall grass.

100. COMPOSITÆ. Composite Family

Flowers epigynous, in a dense head, on a common receptacle, surrounded by an involucre composed of many bracts (Fig. 29), with usually 5 stamens inserted on the corolla, the anthers united into a tube which surrounds the style.

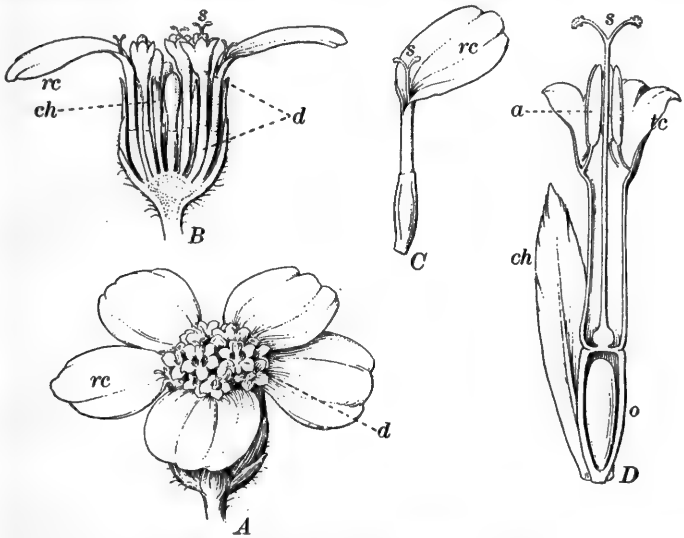


Fig. 29. Flower cluster and flowers of yarrow

A, flower cluster; *B*, section of flower cluster; *C*, a ray flower; *D*, a disk flower. *a*, anthers; *ch*, chaff of disk; *d*, disk flowers; *o*, ovary; *rc*, corollas of ray flowers; *s*, stigmas; *tc*, corolla of tubular flower. (*A*, *B*, *C*, 7 times natural size; *D*, 18 times natural size)

Calyx with its limb sometimes wanting; when present taking the form of scales, bristles, etc., known as *pappus* (Fig. 30). Corolla either strap-shaped (Fig. 29, *rc*) or tubular (Fig. 29, *tc*); in the former case often 5-toothed, in the latter usually 5-lobed. Style 2-cleft above. Fruit an akene, often provided with means of transportation. This is the largest family of flowering plants and among the most specialized for insect

pollination. The genera of the northern United States are divided into two suborders: I. TUBULIFLORÆ, corolla of the bisexual flowers tubular and 5-lobed; II. LIGULIFLORÆ, corollas all strap-shaped and flowers all bisexual.

FIG. 30. Akenes with various types of pappus

A, *Rudbeckia*, pappus wanting; *B*, *Cichorium*, pappus a crown of fine scales; *C*, *Coreopsis*, pappus of 2 small scales; *D*, *Helenium*, pappus a crown of conspicuous scales; *E*, *Cirsium*, pappus a tuft of plumose hairs; *F*, *Lactuca*, pappus borne on a long beak

I. TUBULIFLORÆ[1]

Corollas some or all of them tubular.

Rays white, pink, or purplish.

Rays many; akenes flat; pappus wanting; low herbs. Bellis, I

Rays many; akenes cylindrical or winged, grooved; pappus wanting; tall herbs or shrubby. Chrysanthemum, X

Rays many; akenes flat; pappus of an outer row of minute scales and an inner row of delicate bristles. Erigeron, II

Rays many; akenes cylindrical or ribbed; pappus wanting; strong-scented, branching herbs. Anthemis, IX

Rays few. Achillea, VIII

[1] The characters in this key are not necessarily true of all species in the genera referred to, but only of those described below.

Rays yellow.
Disk purplish-brown. Rudbeckia, IV
Disk gray. Lepachys, V
Disk yellow.
Involucre of 2 rows of bracts, the outer rather leaf-like. Coreopsis, VI
Involucre of reflexed scales; pappus of 5–8 scales. Helenium, VII
Involucre of erect scales; pappus of abundant soft hairs. Senecio, XI
Rays none, but the marginal flowers sterile and their tubular corollas partly flattened like rays. Centaurea, XIII
Rays none, and marginal flowers like the others; scales of the involucre not prickly. Antennaria, III
Rays none and marginal flowers like the others; scales of the involucre overlapping in many rows, prickly-pointed. Cirsium, XII

II. LIGULIFLORÆ

Corollas all strap-shaped.
Corollas blue (rarely pinkish); akenes not beaked. Cichorium, XIV
Corollas blue; akenes beaked. Lactuca, XIX
Corollas yellow.
(*a*) Akenes truncate; pappus double, of chaff and bristles. Krigia, XV
(*b*) Akenes columnar; pappus of tawny, rough bristles; stem scape-like. Hieracium, XXII
(*c*) Akenes spindle-shaped, not beaked; pappus of plumed bristles. Leontodon, XVI

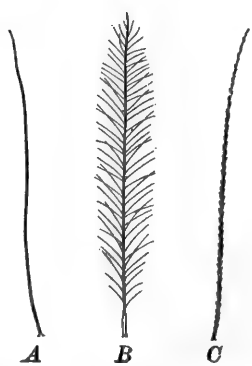


FIG. 31. Types of pappus hairs

A, smooth hair of dandelion; *B*, plumose hair of fall dandelion; *C*, rough or barbed hair of hawkweed. (7 times natural size)

(*d*) Akenes ovoid to spindle-shaped, long-beaked, 4–5-ribbed; pappus white, soft, and abundant. Taraxacum, XVII

(*e*) Akenes nearly as in XVII; pappus tawny. Pyrrhopappus, XXI

(*f*) Akenes not flattened, with or without beak, 10-ribbed; pappus of abundant stiff, hair-like white bristles. Agoseris, XX

(*g*) Akenes flattened, beaked; pappus soft, white, the hairs soon falling off; leafy-stemmed herbs. Lactuca, XIX

(*h*) Akenes flattened, not beaked; pappus abundant, soft, white; leafy-stemmed, spiny-leaved herbs. Sonchus, XVIII

I. TUBULIFLORÆ

I. BELLIS L.

Small herbs. Leaves usually all basal, petioled. Heads solitary, disk yellow, ray flowers white or pink; involucre bell-shaped; bracts in 1 or 2 rows, green; receptacle conical. Ray flowers many, in a single row, pistillate; disk flowers tubular, bisexual, 4–5-toothed; forks of the style short, thick, tipped by roughened cones. Fruit flattened, obovate; pappus wanting.

1. B. integrifolia Michx. AMERICAN DAISY. A branching annual or biennial herb, 4–12 in. high. Upper leaves lanceolate or oblong, the lower ones obovate-spatulate. Heads borne on slender peduncles; rays violet-purple. Prairies, especially S.W.

2. B. perennis L. ENGLISH DAISY, SCOTCH DAISY. An apparently stemless perennial. Leaves obovate-spatulate, smooth or hairy. Heads $\frac{3}{4}$–1 in. in diameter, very pretty, the rays delicate. Cultivated from Europe.

II. ERIGERON L.

Herbs. Leaves usually sessile. Heads many-flowered, flat or nearly hemispherical, the rays numerous, narrow, pistillate. Scales of the involucre narrow and overlapping but little. Akenes flattish, crowned with a single row of hair-like bristles, or sometimes with shorter bristles or scales outside these. Disk yellow, rays white, pinkish, or purple.

B. Fl. species 5 (*Leptilon*).

1. E. pulchellus Michx. Robin's Plantain. Perennial; soft-hairy; stems sometimes throwing out offsets from the base; simple, erect, 1–2 ft. high. Basal leaves obovate-obtuse, somewhat serrate; stem leaves few, lance-oblong, acute, clasping. Heads rather large, 1–9, on long peduncles, with 50–60 long, rather broad, bluish-purple or reddish-purple rays. Thickets and moist banks.

2. E. philadelphicus L. Perennial; rather hairy; stems slender, about 2 ft. high. Basal leaves spatulate and toothed; stem leaves usually entire and strongly clasping, sometimes with a heart-shaped or eared base. Heads several, small, long-petioled; rays exceedingly numerous, thread-like, reddish-purple or flesh color. In damp soil.

3. E. annuus Pers. Common Fleabane. Annual or biennial. Stem grooved and stout, branching, 2–5 ft. high, with scattered hairs. Lowest leaves petioled, ovate, coarsely toothed; those higher up the stem successively narrower, sessile. Heads in a large, loose corymb; rays short, white or purplish. Fields and waste ground.

4. E. ramosus BSP. Daisy Fleabane. Annual or biennial. Considerably resembling the preceding species, but with entire leaves, smaller and less branched stem, smaller heads, and longer rays. Fields and pastures.

5. E. canadensis L. Horseweed, Butterweed, Colt's Tail. Annual; stem erect, 1–5 ft. high. Leaves linear, those of the stem entire. Heads very numerous and small, panicled; the white rays hardly longer than the pappus. A common and troublesome weed.

III. ANTENNARIA Gaertn.

Perennial woolly herbs. Leaves partly basal, the stem leaves alternate. Heads small, many-flowered, diœcious; the flowers all tubular. Involucre of thin, dry, white or colored bracts, imbricated in several series. Receptacle convex or flat, without chaff. Pistillate flowers with very slender tubular corollas and abundant pappus of hair-like, naked bristles, somewhat united at the base; pappus of the sterile flowers thickened and club-shaped at the tips. Akenes small, cylindrical or flattish.

1. A. Parlinii Fernald. Stolons ascending, leafy throughout; stems rather stout, at length 12–20 in. high, they and the stem leaves more or less downy with purplish glandular hairs. Basal leaves and those at the tips of the stolons at length smooth and bright green above; lower stem leaves abundant, oblong or narrower, obtuse or nearly so. Heads corymbed. Style at length crimson. Rich soil, frequently in open woods.

2. A. plantaginifolia Richards. Common Everlasting, Pussy's Toes. Stolons ascending, leafy throughout; stems slender, 4–20 in. high. Basal leaves and those at the tips of the stolons pale and very downy or covered with cobweb-like hairs above; stem leaves scattered, lanceolate, taper-pointed. Heads more or less closely corymbed. Styles crimson. In dry soil, very common.

3. A. solitaria Rydb. Stolons when well developed procumbent, leafy only at the tip; stems 2–8 in. high. Basal leaves obovate-spatulate, densely downy beneath, covered with cobweb-like hairs above, but becoming smoothish; stem leaves few, small, lying close to the stem. Heads solitary. Styles crimson. Rich wooded hillsides, central and south central states.

IV. RUDBECKIA L.

Perennial or biennial. Leaves alternate, entire or lobed. Heads radiate, long-peduncled, many-flowered; bracts imbricated in 2–3 series, spreading; receptacle convex or long-conical, with concave, chaffy scales. Ray flowers yellow, neutral; disk flowers purple to brown, bisexual. Akenes smooth, 4-angled, truncate. Pappus a few short teeth or wanting.*

1. R. hirta L. Cone Flower, Black-Eyed Susan. Annual or biennial; stem erect, rough-hairy, simple or branched, 2–3 ft. high. Leaves lanceolate to oblong, thick, obscurely serrate, rough-hairy, 3-ribbed; the lower petioled, the upper sessile. Heads few, long-peduncled; bracts rough-hairy, spreading. Ray flowers 10–20, orange-yellow; disk flowers purplish-brown. Chaff acute, hairy at the apex. Pappus none. On dry, open ground.

V. LEPACHYS Raf. (RATIBIDA)

Perennial herbs. Leaves alternate, pinnately divided. Heads radiate, long-peduncled, many-flowered; bracts few, small, spreading. Receptacle columnar or slender, the chaff of concave truncate scales. Ray flowers yellow or with brown at the base, neutral; disk usually grayish.

1. L. pinnata T. & G. Gray Cone Flower. Stem slender, branching, often 4 ft. or more high, gray with minute close-lying hairs. Leaves mostly large, pinnately 3–7-divided; the basal ones with long petioles, stem leaves sessile, the uppermost small. Disk oblong, gray or at length brown. Rays 4–10, light yellow, drooping, often 2 in. long. In dry prairie soil and borders of thickets.

2. L. columnaris T. & G. Prairie Cone Flower. Stem rough-hairy, slender, usually branching from the base, 1–2 ft. high. Leaves pinnately divided into oblong to narrowly linear segments. Disk columnar, sometimes more than 1 in. long. Rays 4–10, drooping, yellow or partly or entirely brownish-purple, as long as or somewhat shorter than the disk. On dry prairies, especially W. and S.W.

VI. COREOPSIS L.

Annual or perennial herbs. Leaves opposite or the upper alternate, entire or pinnately divided. Heads radiate, solitary or corymbed, many-flowered; bracts in 2 rows of about 8 each, the inner membranaceous and appressed, the outer narrower and spreading; receptacle chaffy. Ray flowers neutral; disk flowers tubular, bisexual. Akenes compressed, oval to oblong, often winged. Pappus of 2 scales or bristles, or wanting.*

1. C. tinctoria Nutt. Garden Coreopsis. Annual; stem erect, smooth, branched, 2–3 ft. high. Leaves 2–3 times pinnately divided, the divisions linear; lower leaves petioled, the upper often sessile and entire. Heads 1–1½ in. wide, on slender peduncles; inner bracts brown with scarious margins, outer bracts very short. Ray flowers about 8, yellow with a brown base, 3-lobed at the apex. Akenes linear. Pappus minute or none. Common in gardens.*

2. C. lanceolata L. Tickseed. Perennial; stem slender, erect or ascending, smooth or slightly downy below, simple, 9–15 in. high. Leaves opposite, the lower spatulate to elliptical, sometimes lobed, on long, hairy-fringed petioles; the upper lanceolate, sessile. Heads few, on long peduncles; bracts ovate-lanceolate, the outer narrower. Ray flowers 6–10; rays 3–5-lobed, bright yellow. Akenes oval, broadly winged, warty. Pappus of 2 teeth. On rich, dry soil, S. and E.*

3. C. grandiflora Hogg. Large-Flowered Tickseed. Usually perennial; stem smooth, commonly branched above, 1–3 ft. high. Most of the leaves once or twice pinnately parted, the lower sometimes entire, on slender petioles; segments of most of the stem leaves linear or thread-like. Heads usually several, 1¼–2 in. in diameter, on long peduncles; outer bracts lanceolate, narrower and shorter than the inner ones. Rays 6–10, yellow. Akenes oblong, with broad wings when ripe. In moist soil, especially S.W.

4. C. auriculata L. Running Tickseed. Perennial; stem ascending or decumbent, weak, smooth, nearly simple, 6–15 in. long. Leaves ovate to oval, entire or with 2–4 small and rounded lobes at the base, downy, long petioled. Heads 1–1½ in. wide, few or single; outer bracts narrower than the inner. Rays 6–10, mostly 4-toothed

at the apex; chaff as long as the flowers. Akenes oblong, the wings narrow and thickened; pappus of 2 minute teeth. In rich woods.*

5. C. palmata Nutt. STIFF TICKSEED. Perennial; stem stiff, smooth, little or not at all branched, very leafy, 1–3 ft. high. Leaves 3-cleft, broadly wedge-shaped, stiff; the lobes linear-oblong, middle one often 3-lobed. Heads on short peduncles, few or solitary, $1\frac{1}{4}$–2 in. in diameter; bracts of the outer series narrower than the inner ones, slightly shorter. Rays 6–10, bright yellow, broad, usually 3-toothed. Akenes oblong, with narrow wings. Dry prairies and thickets W.

6. C. verticillata L. Perennial; stem smooth, stiff, slender, branching freely, leafy, 1–2 ft. high. Leaves divided into 3 sessile leaflets, the latter once or twice pinnately parted into narrowly linear or thread-like divisions. Heads $1\frac{1}{4}$–$1\frac{1}{2}$ in. in diameter; outer bracts much narrower than the inner ones. Rays 6–10, yellow. Akenes oblong, with narrow wings. In dry or moist soil, sometimes cultivated.

VII. HELENIUM L.

Annual or perennial. Leaves alternate, forming wings on the stem. Heads radiate, peduncled, many-flowered; bracts in 2 series, the outer linear and spreading, the inner few and scale-like; receptacle naked, convex or oblong. Ray flowers pistillate and fertile, or neutral, the rays wedge-shaped, 3–5-lobed; disk flowers bisexual, tubular, 4–5-lobed. Akenes top-shaped, hairy, ribbed; pappus of 4–5 entire, toothed or awned scales.*

1. H. nudiflorum Nutt. SNEEZEWEED. Perennial; stem slender, erect, downy, branched above, 1–2 ft. high. Leaves lanceolate, entire or slightly toothed, the lower petioled, the upper sessile. Heads numerous. Ray flowers 10–15, neutral, yellow or yellow and brown; disk flowers purple. Akenes hairy on the ribs; pappus of ovate, minutely toothed, awned scales. Common on river banks S.*

VIII. ACHILLEA L.

Perennial. Leaves alternate, pinnately divided. Heads with ray flowers in a terminal corymb; involucral bracts imbricated in several series, the outer shorter; receptacle chaffy. Ray flowers white or pink, pistillate and fertile; disk flowers bisexual, tubular, 5-lobed. Akenes oblong, compressed, slightly margined; pappus none.*

1. A. Millefolium L. YARROW. Stems often clustered, erect from a creeping rootstock, simple, downy or woolly, 1–2 ft. high. Leaves

lanceolate or oblong, the segments finely cut and divided, smooth or downy, the lower petioled, the upper sessile. Heads small, numerous, in flat-topped corymbs; bracts downy. Ray flowers 4–5, white or pink, rays 3-lobed at the apex. Common in old fields.*

IX. ANTHEMIS L.

Aromatic or ill-scented herbs. Leaves finely pinnately divided. Heads many-flowered, with ray flowers. Rays pistillate or neutral. Involucre of many small, dry, close-pressed scales. Akenes nearly cylindrical, generally ribbed, barely crowned or naked at the summit.

1. A. Cotula L. MAYWEED, DOG FENNEL. Leaves irregularly cut into very many narrow segments. Heads small, produced all summer. Disk yellow. Rays rather short, white, neutral. A low, offensive-smelling annual weed, by roadsides and in barnyards.

2. A. arvensis L. FIELD CHAMOMILE. Annual or biennial. Resembling *A. Cotula*, but without offensive smell. Leaves less finely once or twice pinnately parted. In fields and waste ground. Naturalized from Europe.

X. CHRYSANTHEMUM L.

Perennials, with toothed, pinnately cut or divided leaves. Heads nearly as in *Anthemis*, except that the ray flowers are pistillate.

1. C. Leucanthemum L. OXEYE DAISY, WHITEWEED, BULL'S-EYE, SHERIFF PINK. Stem erect, unbranched or nearly so, 1–2 ft. high. Basal leaves oblong-spatulate, petioled, deeply and irregularly toothed; stem leaves sessile and clasping, toothed and cut, the uppermost ones shading off into bracts. Heads terminal and solitary, large and showy, with a yellow disk and many white rays. A troublesome but handsome perennial weed. Naturalized from Europe, chiefly E.

2. C. frutescens L. MARGUERITE. Erect, branching, perennial, woody below, smooth, and with a pale bloom. Divisions of the leaves linear, with the uppermost leaves often merely 3-cleft bracts. Heads long-peduncled, showy, with a yellow disk and large, spreading white rays. Cultivated in greenhouses. From the Canary Islands.

XI. SENECIO L.

Annual or perennial; stems often hollow. Leaves alternate, entire or pinnately divided. Heads with or without rays, in terminal corymbs; bracts mostly in a single row, often with a

few shorter ones at the base; receptacle naked or pitted. Ray flowers yellow or orange, pistillate and fertile when present; disk flowers tubular, bisexual. Akenes cylindrical or compressed, not beaked or winged, 5–10-ribbed, downy; pappus of numerous slender white hairs.*

1. **S. glabellus** Poir. BUTTERWEED. Annual; stem erect, ridged, hollow, often woolly when young and becoming smooth with age, branched above, 1–3 ft. high. Leaves lyrate-pinnatifid, thin, the lower petioled, the upper sessile. Heads radiate in a terminal corymb; bracts linear, acute. Ray flowers about 12, yellow. Akenes slightly rough-hairy on the angles; pappus rough, longer than the involucre. Common on low ground.*

2. **S. aureus** L. GOLDEN RAGWEED. Perennial; stems often tufted, erect, slender, woolly when young, branched above, 18–30 in. high. Lower leaves broadly ovate, obtuse at the apex, heart-shaped at the base, crenate, long-petioled; stem leaves lanceolate and often pinnatifid, the upper small and sessile. Heads radiate, corymbed, on slender peduncles. Ray flowers 8–12, bright yellow. Akenes smooth. In wet soil; very variable.*

3. **S. tomentosus** Michx. WOOLLY RAGWEED. Perennial; woolly throughout; stem stout, erect, mostly simple, 2–3 ft. high. Lower leaves ovate to oblong, crenate or entire, obtuse, long-petioled; stem leaves few, elliptical to oblanceolate, serrate or toothed, acute, sessile. Heads radiate, $\frac{3}{4}$ in. wide, on slender peduncles; bracts narrow, becoming smooth. Ray flowers 12–15, yellow. Akenes hairy. In damp soil.*

XII. CIRSIUM Hill. (CARDUUS)

Biennial or perennial; stem erect, simple or branched. Leaves alternate, prickly, often forming wings on the stem. Heads discoid, terminal and solitary or corymbed, many-flowered; bracts overlapping in many series, the outer shorter, usually spine-pointed; receptacle bristly. Corollas purplish or nearly white, the tube slender, deeply 5-cleft. Akenes oblong, 4-angled, smooth or ribbed; pappus of numerous simple or plumose bristles. [Most of our commoner species blossom in the late summer and autumn.]*

1. **C. spinosissimum** Scop. YELLOW THISTLE. Biennial or perennial; stem erect, stout, woolly when young, becoming smooth, often purple, branched, 1–3 ft. high. Leaves pinnately cut, with very spiny teeth, mostly sessile and clasping, smooth and green on both sides. Heads

large, surrounded by a whorl of linear-oblong, comb-like leaves; involucral bracts linear, ciliate, not spine-tipped. Flowers purple or yellowish. On sandy soil E. and S.*

2. C. virginianum Michx. EARLY WOOD THISTLE. Stem woolly, slender, little or not at all branched, 1–3 ft. high. Leaves lanceolate, green above, covered beneath with dense white wool, the margins beset with prickly bristles, entire or sinuate-lobed, the lower ones sometimes pinnately cut into triangular-lanceolate lobes. Heads small, purple, on long leafless peduncles; outer scales of the involucre merely bristle-pointed. In dry woods and thickets.

XIII. CENTAUREA L.

Herbs. Leaves entire or cut, often spiny-toothed. Heads single; involucre ovoid or globose; bracts closely overlapping, often fringed, dry and membranaceous. Corollas all tubular, oblique or 2-lipped, inflated above; the outer ones usually larger and neutral, the inner flowers bisexual; lobes 5, slender. Akenes flattened; pappus hairs short, slender, rough.

1. Cyanus L. BACHELOR'S BUTTON. Stem erect, slender, grooved, 1–2 ft. high, somewhat branched. Leaves acute, sessile, narrow, entire or few-lobed. Peduncles covered with cottony wool. Heads $\frac{1}{2}$–1 in. in diameter, cobwebby. Ray-like flowers few, large, bright blue or pink; those of the disk smaller. Cultivated from Europe and escaped from gardens.

2. C. americana Nutt. PRAIRIE STAR THISTLE. Annual; stem stout, little or not at all branched, 2–6 ft. high. Leaves entire or minutely toothed, the basal and lower ones spatulate or oblong, petioled, the upper narrower, sessile and mucronate. Heads solitary at the summit of the stem or tips of the branches; involucre nearly hemispherical, the bracts ovate or lanceolate, with comb-like appendages. Flowers pink or purple, the marginal ones ray-like. In dry plains, especially S.W.

II. LIGULIFLORÆ

XIV. CICHORIUM L.

Perennial herbs with spreading branches; juice milky. Leaves radical and alternate, toothed or pinnately cut. Heads axillary; involucre cylindrical; bracts in 2 rows, the inner row erect, united at the base, the outer shorter; receptacle flattish. Corollas blue, pale pink, or yellow. Upper part of the style and its slender arms hairy. Akenes crowded on the

hardened receptacle, firmly covered by the stiff involucre, obovoid or top-shaped, not beaked; pappus 1 or 2 rows of short scales.

1. C. Intybus L. CHICORY, BLUE DANDELION, BLUE SAILORS. Root very long, stout, and fleshy; stem 1–3 ft. high, angled and grooved; branches straight and stiff. Basal leaves and lower stem leaves runcinate; upper stem leaves oblong or lanceolate, clasping, those of the branches reduced to bracts. Flowers very showy, usually bright blue, rarely pinkish-white. Introduced from Europe; a troublesome weed in grass lands and common in waste places, particularly in New England.

XV. KRIGIA Schreber. (ADOPOGON)

Small, annual or perennial herbs. Leaves mostly basal, toothed or lyrate. Heads several–many-flowered; scales of the involucre about 2-rowed, thin. Akenes short, truncate; pappus in 2 rows, the outer one of thin, blunt, chaffy scales, the inner one of slender bristles. Corollas yellow.

1. K. virginica Willd. Annual; scapes usually 2–5 from one root, slender. Leaves mostly lyrate, smooth and with a bloom, the earlier ones rounded or spatulate. Scales of the involucre linear-lanceolate, nearly equal, spreading. Akenes top-shaped, reddish-brown, crowned with 5 wedge-obovate scales and 5 rough white bristles.

2. K. Dandelion Nutt. Perennial, from slender tuber-bearing roots; scapes leafless, 6–18 in. high. Leaves entire or nearly so, varying from spatulate-oblong to linear-lanceolate. Akenes more slender than in No. 1; pappus consisting of 10–15 small, oblong, chaffy scales, and 15–20 bristles. In moist ground, especially S.

3. K. amplexicaulis Nutt. Stem 12–18 in. high, often 2–3 from the same root, mostly 2-forked or 3-forked at the summit. Basal leaves 3–6 in. long, lanceolate, entire, toothed or rarely pinnately cut, clasping at the base; stem leaves 1–3. Akenes and pappus about as in No. 2. Moist banks.

XVI. LEONTODON L.

Perennial, scape-bearing herbs; juice milky. Leaves all basal, toothed or pinnatifid, often runcinate. Heads on simple or branched scapes, yellow; bracts of the involucre many, in several rows, the anther smaller; receptacle flat, naked. Arms of the style linear, obtuse, hairy. Akenes cylindrical, grooved, transversely wrinkled; beak short; pappus hairs stiff, in 1 or 2 rows.

1. L. autumnalis L. Scape usually branching, 5–15 in. high, bracted; peduncles enlarged above. Rootstock truncate. Heads $1\frac{1}{2}$–1 in. or more in diameter; involucre top-shaped or bell-shaped. Pappus of a single row of tawny hairs. Fields and roadsides, especially N.E. Naturalized from Europe.

XVII. TARAXACUM Haller

Stemless perennial or biennial herbs. Leaves in a flattish tuft, pinnately cut or runcinate. Head many-flowered, large, solitary, yellow, borne on a hollow scape, which is short at first but lengthens after flowering. Involucre composed of a single row of long, erect inner scales, and a set of much shorter ones outside and at the base of the former ones. Akenes cylindrical or spindle-shaped, with 4–5 rough ribs, the apex tapering into a bristle-like beak which bears a short, broadly conical tuft of soft white hairs.

1. T. officinale Weber. DANDELION. Outer involucre reflexed; inner involucre closing over the head, after the flowers are withered, and remaining shut for some days, then opening and allowing the akenes to form a globular head. Root stout, bitter, medicinal. Young leaves eaten as a pot-herb ("greens") in spring — the plant often cultivated for the leaves by market-gardeners.

XVIII. SONCHUS L.

Annual or perennial. Leaves mostly toothed or pinnately cut, prickly margined. Heads in corymbs or panicles; bracts in several series, the outer shorter; receptacle naked. Flowers yellow, rays truncate, 5-toothed at the apex. Akenes oval to oblong, compressed, ribbed, truncate at the apex; pappus of numerous soft white hairs.*

1. S. oleraceus L. SOW THISTLE. Annual; stem erect, branched, smooth, 2–6 ft. high. Leaves spiny-toothed, the lower long-petioled, very irregularly cut or pinnatifid, the upper clasping by an eared base. Involucre downy when young. Akenes channeled and transversely wrinkled. In waste places on very rich soil.*

2. S. asper Vill. SPINY SOW THISTLE. Annual; stem erect, smooth, branched but little, 2–6 ft. high. Leaves undivided, spatulate to oblanceolate, fringed with spiny teeth; the lower narrowed into a petiole, the upper clasping by an eared base, the ears rounded.

Heads numerous; involucre glabrous. Akenes flattened, margined, 3-nerved on each side, smooth. In waste places.*

XIX. LACTUCA L.

Annual, biennial, or perennial; stems leafy. Leaves entire to pinnately cut. Heads panicled; involucre cylindrical; bracts unequal, overlapping in 2 or more rows, the outer shorter; receptacle naked. Flowers blue, yellow, or white; rays truncate, 5-toothed at the apex. Akenes compressed, ribbed, the apex contracted into a slender beak, which is enlarged into a disk bearing the soft, hairy, white or tawny pappus.*

1. **L. canadensis** L. WILD LETTUCE. Biennial; stem erect, smooth, hollow, branched above, 3–10 ft. high. Leaves lanceolate to spatulate, pale beneath, the lower petioled and pinnately cut, the upper sessile, clasping, and nearly entire. Heads numerous, about 20-flowered; flowers yellow. Akenes oval, flat, 1-ribbed on each side, minutely roughened, about as long as the beak; pappus white. In waste places.*

2. **L. acuminata** Gray. BLUE LETTUCE. Stem very leafy, smooth, paniculately branched above, 3–6 ft. high. Leaves ovate to lanceolate, taper-pointed, often hairy beneath; the lower on winged petioles and often sinuate-lobed, the upper sessile. Heads racemed, on divergent and bracted peduncles; flowers blue. Akenes slightly compressed, beak very short; pappus white. In waste places.*

XX. AGOSERIS Raf.

Herbs, usually appearing stemless. Basal leaves tufted, usually sessile. Head solitary, large, yellow or rarely purple, on a naked or bracted scape; bracts of the involucre overlapping in 2 or 3 rows; receptacle flat, naked or pitted. Akenes smooth, 10-ribbed, with or without a beak; pappus of abundant slender white bristles.

B. Fl. species 1 (*Nothocalais*).

1. **A. cuspidata** Steud. Scape 1 ft. or more high. Leaves lanceolate, taper-pointed, woolly-margined. Involucral scales lanceolate, sharp-pointed. Akenes beakless. Prairies and plains W.

2. **A. glauca** Steud. Scape stout, 1–2 ft. high. Leaves varying from linear to oblong, entire, dentate or pinnately cut. Heads 1–2 in. in diameter. Akenes beaked. Plains W.

XXI. PYRRHOPAPPUS DC. (SITILIAS)

Annual or biennial; stem erect, leafy below, nearly naked above, smooth. Leaves oblong, toothed or pinnatifid. Heads large, long-peduncled; involucre cylindrical or spreading, the inner row of bracts erect, united at the base, the outer rows shorter and spreading; receptacle naked. Flowers yellow; rays truncate, 5-toothed at the apex. Akenes oblong, 5-ribbed, narrowed above into a long and slender beak; pappus soft, tawny, with a short, soft-hairy ring at the base.*

1. P. carolinianus DC. FALSE DANDELION. Annual or biennial; stem glabrous, furrowed, branched above, 2–3 ft. high. Lower leaves lanceolate to oblong, entire, toothed or pinnatifid, narrowed into a margined petiole; the upper sessile, bract-like, entire. Heads few, long-peduncled; peduncles and involucre sometimes finely downy; inner bracts calloused at the apex, the outer awl-shaped and spreading. Akenes much shorter than the thread-like beak. Common in fields.*

XXII. HIERACIUM L.

Perennial herbs, often covered with glandular or star-shaped hairs; juice milky. Leaves alternate. Heads solitary, or in corymbs or panicles; bracts of the involucre many, overlapping, unequal; receptacle flattish, naked, pitted. Corollas yellow, rarely orange. Arms of the style slender and upper part of the style hairy; akenes angled or grooved, not beaked. Pappus hairs in a single row, simple, stiff, tawny or brownish, brittle. [Most of our commoner species bloom in the late summer or autumn.]

1. H. aurantiacum L. ORANGE HIERACIUM, DEVIL'S PAINT BRUSH. Stem leafless or occasionally with 1 or 2 small sessile leaves, clothed with long hairs. Basal leaves oblanceolate, hairy, 2½–6 in. long. Scapes 8–24 in. high. Heads corymbed, about ¾ in. in diameter, orange-red. A common weed, naturalized from Europe.

2. H. venosum L. RATTLESNAKE WEED. Stem scape-like, usually leafless or nearly so, smooth, 1–2 ft. high. Basal leaves 2–5 in. long, obovate or ovate-oblong, generally purple-veined. Heads rather large, yellow, in a loose panicled corymb. Dry hills and roadsides, and in pine woods E.

GLOSSARY

OF TECHNICAL TERMS USED MAINLY IN THE FLORA

Abortive, imperfectly developed.

Actinomorphic, having radial symmetry.

Adventive, partially naturalized.

Appressed, lying flat throughout its length, used of such parts as bracts.

Awl-shaped, narrow and tapering to a point.

Awned, having a bristle-like appendage.

Awnless, not awned.

Bisexual, having both stamens and pistils in the same flower.

Caducous, falling away very early.

Capitate: (1) having a round head like the stigma of a primrose; (2) growing in heads.

Carpellary, relating to a carpel.

Chaff, small membranous scales, such as are found on disks of *Compositæ*.

Ciliate, having the margins fringed with hairs or bristles.

Clasping, partly surrounding the stem; said of the bases of leaves.

Claw, the narrowed base of a petal.

Cleft, cut halfway down.

Coated (bulbs), those with scales which completely cover them, as in the onion.

Cone, the fruit of pines, etc., with ovule-bearing scales.

Connate, united; said of opposite leaves which appear as if grown together at their bases.

Convolute

Convolute, rolled up lengthwise.

Cordate, heart-shaped.

Corm, a bulb-like, fleshy stem or base of a stem.

Crown, an inner appendage to a petal or to the throat of the corolla.

Deciduous, falling as petals do after blossoming, or as leaves of most trees except evergreens do.

Declined, directed obliquely.

Decumbent, reclining, but with the summit somewhat erect.

Dehiscent, splitting into definite parts.

Diffuse, spreading widely or loosely.

Dimorphous, occurring under two forms, as in flowers with long and with short styles.

Disk: (1) an outgrowth of the receptacle within the calyx or within the corolla and stamens; (2) the central part of the head (all but the rays) in *Compositæ*.

Dissected, deeply divided or cut into many segments.

Drupe, a stone fruit such as a peach or a plum.

Equitant, leaves astride of those within them, thus appearing in a cross section like the diagram, <<<.

Even-pinnate, abruptly pinnate, i.e. with no leaflet at the end.

Fascicle, a close cluster or bundle of flowers, leaves, stems, or roots.

Fertile, capable of producing fruit; fertile flowers, those which have pistils.

Filiform, thread-shaped.

Fleshy, succulent, thick and full of sap.

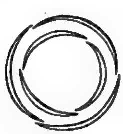
Funiculus, the little stalk which connects a seed or ovule with the placenta.

Gland: (1) a structure which secretes something, as the knobs on the hairs of sundew; (2) any knob or swelling.

Glume, one of the two sterile, chaffy bracts at the base of a grass spikelet.

Herbaceous, with no stem aboveground which lives through the winter, not woody or shrubby.

Imbricate, overlapping, as the segments of some perianths in the bud. At least one segment must be wholly outside and one wholly inside.



Imbricate

Indefinite, too many to be easily counted.

Indehiscent, not splitting open regularly.

Introduced, term applied to plants purposely brought into a region by man.

Involucrate, provided with an involucre.

Keel, the two anterior and united petals of a papilionaceous corolla.

Key, a winged fruit like that of the ash or maple.

Limb, the border or spreading part of a gamopetalous calyx or corolla.

Lobed, having divisions, especially rounded ones.

Lodicule, one of the very minute scales immediately beneath each flower in a grass spikelet.

Naturalized, term applied to plants not natives of a region but thoroughly established there in a wild condition.

Nerved, having simple or unbranched veins or slender ribs.

Ob- (in composition), signifies inversely; as, obcordate, inversely heart-shaped.

Odd-pinnate, pinnate with a single leaflet at the end of the midrib.

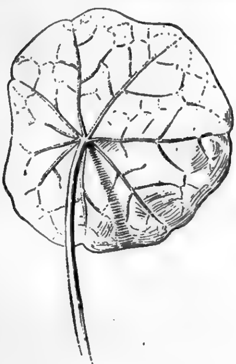
Palate, a projection in the throat of a corolla.

Palet, one of the bracts which subtend the flowers in a grass spikelet.

Papilionaceous, butterfly-shaped, like the corolla of the sweet pea.

Papillose, covered with papillæ or minute projections, like the human tongue.

Pappus, tufts of hair or other objects, representing the limb of the calyx in *Compositæ* (Fig. 30).



Peltate

Peltate, shield-shaped, that is with the stalk attached somewhere within the circumference of the leaf or other organ.

Perfoliate, with the stem apparently growing up through a leaf, as in some honeysuckles.

Persistent, not deciduous.

Pinnatifid, pinnately cleft.

Pistillate, having pistils but not stamens.

Plumose, feathered, as the pappus of thistles (Fig. 31).

Pubescent, clothed with soft hair, downy.

Punctate, marked with dots, depressions, or translucent glands.

Reflexed, bent or turned abruptly downward or backward.

Root parasite, a plant parasitic on the roots of another.

Sagittate, arrow-shaped.

Scape, a leafless flower stalk arising from the ground, as in the dandelion and cyclamen.

Scarious, thin, dry, and membranous, not green.

Sessile, without a stalk.

Simple (stem), unbranched.

Spadix, a spike with a fleshy axis, like that of the Indian turnip or the "calla."

Spathe, a large bract which incloses a flower cluster, often a spadix.

Staminate, having stamens only.

Standard, the posterior petal of a papilionaceous corolla.

Sterile: (1) barren, as a flower without a pistil or an antherless stamen; (2) staminate or male, said of flowers.

Striate, marked with fine longitudinal parallel lines.

Sub- (in composition), somewhat, as subglobose.

Subtend, to extend beneath as a bract in the axil of which a flower is borne.

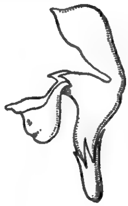
Succulent, fleshy or juicy.

Three-ranked, with three vertical rows on a stem or axis.

Throat, the top of the tubular part of a sympetalous corolla.

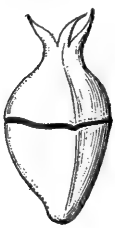
Truncate, appearing as if cut squarely off, as the leaves of the tulip tree.

Tubercled, covered with warty growths.



Two-lipped

Tubercular, having tubercles, or like a tubercle.



Utricle

Two-lipped, having the limb of the calyx or corolla divided into two lip-like portions, as in the *Labiatæ*.

Two-ranked, with two vertical rows on a stem or axis.

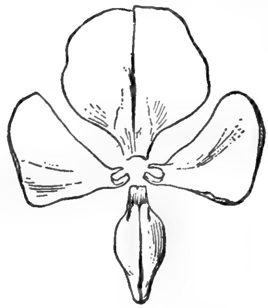
Unisexual, having in each flower only stamens or only pistils, not both.

Utricle, a small bladdery ovary wall.

Versatile, turning freely on its support, as an anther on its filament.

Whorled, arranged in a circle around an axis, as the leaves of some lilies.

Wings, the side petals of a papilionaceous flower.



Zygomorphic

Zygomorphic, having bilateral symmetry, as the corollas of many *Leguminosæ*.

INDEX

All names in italics are synonyms, — the preferred names are in Roman type